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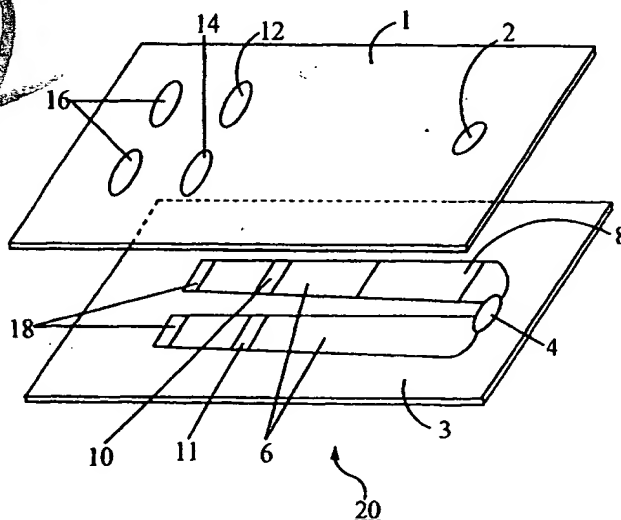
(57) Abstract

The present invention relates to rapid methods for the detection of ischemic states and to kits for use in such methods. Provided for is a rapid method of testing for and quantifying ischemia based upon methods of detecting and quantifying the existence of an alteration of the serum protein albumin which occurs following an ischemic event; methods for detecting and quantifying this alteration include evaluating and quantifying the cobalt binding capacity of circulating albumin, analysis and measurement of the ability of serum albumin to bind exogenous cobalt, detection and measurement of the presence of endogenous copper in a purified albumin sample and use of an immunological assay specific to the altered form of serum albumin which occurs following an ischemic event. Also taught by the present invention is the detection and measurement of an ischemic event by measuring albumin N–terminal derivatives that arise following an ischemic event, including truncated albumin species lacking one to four N–terminal amino acids or albumin with an acetylated N–terminal Asp residue.

TESTS FOR THE RAPID EVALUATION OF ISCHEMIC STATES AND KITS

BACKGROUND OF THE INVENTION

1.   Field of the Invention

The present invention relates to rapid methods for the detection of ischemic states and to kits for use in such methods. More particularly, the invention relates to the measurement of a bound specific transition element to human serum albumin or the measurement of albumin N-terminal derivatives to determine the presence or absence of ischemia.

2.   Discussion of the Background

Ischemia is the leading cause of illness and disability in the world. Ischemia is a deficiency of oxygen in a part of the body causing metabolic changes, usually temporary, which can be due to a constriction or an obstruction in the blood vessel supplying that part. The two most common forms of ischemia are cardiovascular and cerebrovascular. Cardiovascular ischemia, in which the body's capacity to provide oxygen to the heart is diminished, is the leading cause of illness and death in the United States. Cerebral ischemia is a precursor to cerebrovascular accident (stroke) which is the third leading cause of death in the United States.

The continuum of ischemic disease includes five conditions: (1) elevated blood levels of cholesterol and other blood lipids; (2) subsequent narrowing of the arteries; (3) reduced blood flow to a body organ (as a result of arterial narrowing); (4) cellular damage to an organ caused by a lack of oxygen; (5) death of organ tissue caused by sustained oxygen deprivation. Stages three through five are collectively referred to as "ischemic disease," while stages one and two are considered its precursors.

Together, cardiovascular and cerebrovascular disease accounted for 954,720 deaths in the U.S. in 1994. Furthermore, more than 20% of the population has some form of cardiovascular disease. In 1998, as many as 1.5 million Americans will have a new or recurrent heart attack, and about 33% of them will die. Additionally, as many as 3 to 4 million Americans suffer from what is referred to as "silent ischemia." This is a condition where no clinical symptoms of ischemic heart disease are present.

There is currently a pressing need for the development and utilization of blood tests able to detect injury to the heart muscle and coronary arteries. Successful

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treatment of cardiac events depends largely on detecting and reacting to the presence of cardiac ischemia in time to minimize damage. Cardiac enzymes, specifically the creatine kinase isoenzyme (CK-MB), and cardiac markers, specifically the Troponin I and T biochemical markers, are utilized for diagnosing heart muscle injury. However,

5   these enzymes and markers are incapable of detecting the existence of an ischemic state in a patient prior to myocardial infarction and resulting cell necrosis (death of cell). Additionally, these enzymes and markers do not show a measurable increase until several hours after an ischemic event. For instance, CK-MB, the earlier evident of the two, does not shows a measurable increase above normal in a person's blood

10   test until about four to six hours after the beginning of a heart attack and does not reach peak blood level until about 18 hours after such an event. Thus, the primary shortcoming of using cardiac markers for diagnosis of ischemic states is that these markers are only detectable after heart tissue has been irreversibly damaged.

There currently are no tests available which allow diagnosis of the existence of

15   ischemia in patients prior to tissue necrosis. A pressing requirement for emergency medicine physicians who treat chest pain and stroke symptoms is for a diagnostic test that would enable them to definitively "rule out" myocardial infarction, stroke, and other emergent forms of ischemia. A need exists for a method for immediate and rapid distinction between ischemic and non-ischemic events, particularly in patients

20   undergoing acute cardiac-type symptoms. The present invention provides such a means.

A broader array of diagnostic tests are available for diagnosis of ischemia in patients with non-acute symptoms. The EKG exercise stress test is commonly used as an initial screen for cardiac ischemia, but is limited by its accuracy rates of only 25-

25   50%. Coronary angiography, an invasive procedure that detects narrowing in the arteries with 90-95% accuracy, is also utilized. Another commonly used diagnostic test is the thallium exercise stress test, which requires injection of radioactive dye and serial tests conducted four hours apart. The present invention, however, has the advantage over the known methods of diagnosis in that it provides equivalent or better

30   accuracy at far lower costs and decreased risk and inconvenience to the patient. The

present invention provides specificity and sensitivity levels of 75-95%, which are far more accurate than the EKG exercise stress test and comparable in accuracy to current diagnostic standards. Furthermore, the present invention presents a significant time advantage and is cheaper than competing methods of diagnosis by a factor of at least

5 15 to 1.

It is known that immediately following an ischemic event, proteins (enzymes) are released into the blood. Well known proteins released after an ischemic heart event include creatine kinase (CK), serum glutamic oxalacetic transaminase (SGOT) and lactic dehydrogenase (LDH). One well known method of evaluating the

10 occurrence of past ischemic heart events is the detection of these proteins in a patient's blood. U.S. Pat. No. 4,492,753 relates to a similar method of assessing the risk of future ischemic heart events. However, injured heart tissue releases proteins to the bloodstream after both ischemic and non-ischemic events. For instance, patients undergoing non-cardiac surgery may experience perioperative ischemia. Electro-

15 cardiograms of these patients show ST-segment shifts with an ischemic cause which are highly correlated with the incidence of postoperative adverse cardiac events. However, ST-segment shifts also occur in the absence of ischemia; therefore, electrocardiogram testing does not distinguish ischemic from non-ischemic events. The present invention provides a means for distinguishing perioperative ischemia

20 from ischemia caused by, among other things, myocardial infarctions and progressive coronary artery disease.

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SUMMARY OF THE INVENTION

The present need for rapid, immediate and continuous detection of ischemic states is met by the present invention. Specifically, the present invention provides for rapid methods of testing for the existence of and quantifying ischemia based upon methods of detecting and quantifying the existence of an alteration of the serum protein albumin which occurs following an ischemic event. Preferred methods of the present invention for detecting and quantifying this alteration include evaluating and quantifying the metal binding capacity of albumin, analysis and measurement of the ability of serum albumin to bind exogenous metal, detection and measurement of the presence of endogenous copper in a purified albumin sample, use of an immunological assay specific to albumin-metal complexes, and detection and measurement of albumin N-terminal derivatives that arise following an ischemic event. Also taught by the present invention is the use of the compound Asp-Ala-His-Lys-R, wherein R is any chemical group capable of being detected when bound to a metal ion that binds to the N-terminus of naturally occurring human albumin, for detection and quantitation of an ischemic event.

Advantages and embodiments of the invention include a method for ruling-out the existence of an ischemic state or event in a patient; a method for detecting the existence of asymptomatic ischemia; a method for evaluating patients with angina to rule-out the recent occurrence of an ischemic event; an immediate method for evaluation of patients suffering from chest pain to detect the recent occurrence of a myocardial infarction; a method for evaluation of patients suffering from stroke-like signs and symptoms to detect the occurrence of a stroke and to distinguish between the occurrence of an ischemic stroke and a hemorrhagic stroke; a rapid method for supplementing electrocardiographic results in determining the occurrence of true ischemic events; a method for detecting the occurrence of a true ischemic event in a patient undergoing surgery; a method for evaluating the progression of patients with known ischemic conditions; a method for comparing levels of ischemia in patients at rest and during exercise; a method for assessing the efficacy of an angioplasty procedure; a method for assessing the efficacy of thrombolytic drug therapy; a

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method for assessing the patency of an in-situ coronary stent; and, a method for detecting in a pregnant woman the occurrence of placental insufficiency.

Additional advantages, applications, embodiments and variants of the invention are included in the Detailed Description of the Invention and Examples

5   sections.

As used herein, the term "ischemic event," and "ischemic state" mean that the patient has experienced a local and/or temporary ischemia due to partial or total obstruction of the blood circulation to an organ. Additionally, the following abbreviations are utilized herein to refer to the following amino acids:

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Amino acid	Three-letter abbreviation	Single-letter notation
Alanine	Ala	A
Arginine	Arg	R
Asparagine	Asn	N
Aspartic acid	Asp	D
Asparagine or aspartic acid	Asx	B
Cysteine	Cys	C
Glutamine	Gln	Q
Glutamic acid	Glu	E
Glutamine or glutamic acid	Glx	Z
Glycine	Gly	G
Histidine	His	H
Isoleucine	Ile	I
Leucine	Leu	L
Lysine	Lys	K
Methionine	Met	M
Phenylalanine	Phe	F
Proline	Pro	P
Serine	Ser	S
Threonine	Thr	T
Tryptophan	Trp	W
Tyrosine	Tyr	Y
Valine	Val	V

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A separate test method for ischemia was described by a common inventor in U.S. Patents Nos. 5,227,307 and 5,290,519 to Bar-Or et al., herein incorporated by reference in their entirety. Also incorporated herein in their entireties by reference are the following commonly assigned applications: U.S. Serial No. 09/165,926, filed October 2, 1998; U.S. Serial No. 09/165,581, filed October 2, 1998; and U.S. Serial No. 60/115,392, filed January 11, 1999.

BRIEF DESCRIPTION OF THE FIGURES

Figs. 1-3 illustrate kits useful in carrying out the derivative embodiment of the subject invention.

Fig. 4 shows selected regions of the ^{1}H-NMR spectra (500 MHz, 10% D_2O in H_2O, 300K) showing the Ala resonances (Ala-2 and Ala-8) of the octapeptide (Asp-Ala-His-Lys-Ser-Glu-Val-Ala) (a) free of any metal, with a Lys-4 methylene resonance appearing between the doublets, (b) with 0.5 equiv. of $NiCl_2$ added, (c) with 1.0 equiv. of $NiCl_2$ added, (d) with 0.5 equiv. of $CoCl_2$ added, and (e) with 1.0 equiv. of $CoCl_2$ added.

Figs. 5A and 5B are ultraviolet spectra for non-acetylated Pep-12 (Asp-Ala-His-Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys) and acetylated Pep-12, respectively.

Figs. 6A and 6B are ultraviolet spectra for non-acetylated Pep-12 and acetylated Pep-12 each with $CoCl_2$, respectively.

Fig. 7 provides spectral analysis of five solutions of increasing proportions of acetylated Pep-12 to non-acetylated Pep-12 with effect on cobalt binding as reflected by a shift in absorbance from 220 to 230.

Figs. 8A and 8B are U.V. spectra of Pep-12 and acetylated Pep-12, respectively, mixed first with $CuCl_2$ and then with $CoCl_2$.

Fig. 9 is the U.V. spectra of acetylated Pep-8 (Asp-Ala-His-Lys-Ser-Glu-Val-Ala) which did not shift upon addition of cobalt.

Figs. 10A-D are the ^{1}H-NMR spectra of Peptide 1 (Asp-Ala-His-Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys) which shows the methyl signals of the two Ala residues at

positions 2 and 8 as titrated by NiCl$_2$. Fig. 10A is Peptide 1 at pH 2.55, while 10B is at pH 7.33. Fig. 10C is the spectra at pH 7.30 with 0.3 equiv. NiCl$_2$, and Fig. 10D is pH 7.33 at ~ 1 equiv. NiCl$_2$.

5 Figs. 11A-D are the ^{1}H-NMR spectra of Peptide 1 (Asp-Ala-His-Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys) which shows the methyl signals of the two Ala residues at positions 2 and 8 as titrated by CoCl$_2$. Fig. 11A is Peptide 1 at pH 2.56, while 11B is at pH 7.45. Fig. 11C is the spectra at pH 7.11 with ~0.5 equiv. CoCl$_2$, and Fig. 11D is pH 7.68 at ~ 1 equiv. CoCl$_2$.

10 Figs. 12A-D are the ^{1}H-NMR spectra of Peptide 1 (Asp-Ala-His-Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys) which shows the methyl signals of the two Ala residues at positions 2 and 8 as titrated by CuSO$_4$. Fig. 12A is Peptide 1 at pH 2.56, while 12B is at pH 7.54. Fig. 12C is the spectra at pH 7.24 with ~0.5 equiv. CuSO$_4$, and Fig. 12D is pH 7.27 at ~ 1 equiv. CuSO$_4$.

15 Figs. 13A-D are the ^{1}H-NMR spectra of Peptide 2, which is the acetylated-Asp version of Peptide 1. Fig. 13A is Peptide 2 at pH 2.63. Fig. 13B is Peptide 2 at pH 7.36. Fig. 13C is Peptide 2 at pH 7.09 with ~0.5 equiv. NiCl$_2$. Fig. 13D is Peptide 2 at pH 7.20 with ~1 equiv. NiCl$_2$.

Figs. 14A-E are the ^{1}H-NMR spectra of Peptide3 (Ala-His-Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys). Fig. 14A is Peptide 3 at pH 2.83. Fig. 14B is Peptide 3 at pH

20 7.15. Fig. 14C is Peptide 3 at pH 7.28 with ~ 0.13 equiv. NiCl$_2$. Fig. 14D is Peptide 3 at pH 7.80 with ~0.25 equiv. NiCl$_2$. Fig. 14E is Peptide 3 at pH 8.30 with ~0.50 equiv. NiCl$_2$.

Figs. 15A-D are the ^{1}H-NMR spectra of Peptide 4 (His-Lys-Ser-Glu-Val-ala-His-Arg-Phe-Lys). Fig. 15A is Peptide 4 at pH 2.72. Fig. 15B is Peptide 4 at pH

25 7.30. Fig. 15C is Peptide 4 at pH 8.30 with ~0.5 equiv. NiCl$_2$. Fig. 15D is Peptide 4 at pH 8.10 with ~1 equiv. NiCl$_2$.

Figs. 16A-D are the ^{1}H-NMR spectra of Peptide 5 (Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys). Fig. 16A is Peptide 5 at pH 2.90. Fig. 16B is Peptide 5 at pH 7.19.

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Fig. 16C is Peptide 5 at pH1.02 with ∼0.3 equiv. NiCl₂. Fig. 16D is Peptide 5 pH 7.02 with ∼0.6 equiv. NiCl₂.

Figs. 17A-D are ¹H-NMR spectra of the N-terminal tetrapeptide, Asp-Ala-His-Lys. Fig. 17A is at pH 2.49. Fig. 17B is at pH7.44. Fig. 17C is at pH 7.42 with ∼0.8 equiv. NiCl₂. Fig. 17D is at pH 7.80 with ∼1 equiv. NiCl₂.

Figs. 18A-C are ¹H-NMR spectra of the N-terminal tetrapeptide with CoCl₂. Fig. 18A is at pH 7.44. Fig. 18B is at pH 7.23 with ∼0.3 equiv. CoCl₂. Fig. 18C is at pH 7.33 with ∼0.8 equiv. CoCl₂.

Figs. 19A-C are ¹H-NMR spectra of the N-terminal tetrapeptide with CuSO₄. Fig. 19A is at pH 7.31. Fig. 19B is at pH 7.26 with ∼0.5 equiv. CuSO₄. Fig. 19C is at pH 7.32 with ∼ 1.0 equiv. CuSO₄.

DETAILED DESCRIPTION OF THE INVENTION

A number of terms used herein have the following definitions.

"Albumin-metal complex" or "metal-albumin complex" means the complex of a divalent cation, including but not limited to copper, cobalt and nickel, to the N-terminus of naturally-occurring albumin.

"Albumin N-terminus" refers to that portion of naturally-occurring albumin constituting comprising at least the four N-terminal amino acids, i.e., Asp-Ala-His-Lys.

"Albumin N-terminal derivatives" refers to those species of albumin that are altered or truncated at the N-terminus as a result of an ischemic event. Specifically, the derivatives include those albumin species lacking 4, 3, 2 and 1 N-terminal amino acid, as well as a full-length albumin that is acetylated at its terminal Asp residue. Albumin –terminal derivatives cannot form albumin-metal complexes and may be found in the blood of ischemic patients. Full-length, naturally-occurring albumin is set forth is SEQ. ID. NO. 1. Acetylated-Asp albumin is set forth in SEQ. ID. NO. 2.

"Antibody to an albumin-metal complex" is an antibody to the epitope formed of the metal and surrounding amino acids and/or their side chains.

"Derivative N-terminus" refers to the 4-12 amino acids at the N-terminus of albumin N-terminal derivatives, which may serve as an epitope in the generation of a monoclonal antibody.

"Endogenous copper" refers to copper present in a patient sample of albumin, i.e., not exogenously added during the diagnostic procedure.

"Excess quantity" of metal ion or "excess metal ion" refers to addition of an amount of metal ion that will substantially exceed the stoichiometrically available albumin metal ion binding sites such that substantially all naturally-occurring albumin is bound to metal ion at its N-terminus.

"Known value" as used herein means a clinically-derived cut-off value or a normal range, to which a measured patient value is compared so as to determine the occurrence or non-occurrence of an ischemic event.

"Naturally-occurring albumin" refers to albumin with an intact N-terminus (Asp-Ala-His-Lys–) that has not been acetylated.

"Purified albumin" or "purified albumin sample" refers to albumin that has been partially purified or purified to homogeneity. "Partially purified" means with increasing preference, at least 70%, 80%, 90% or 95% pure.

"Treadmill test" means a stress test to increase myocardial O_2 demand, while observing if a mismatch occurs between demand and supply by observing symptoms such as shortness of breath, chest pain, EKG, low blood pressure and the like.

While not being bound by any particular theory, it is believed that the present method works by taking advantage of alterations which occur to the albumin molecule, affecting the N-terminus of albumin during an ischemic ("oxygen-depletion") event. (Ischemia occurs when human tissue is deprived of oxygen due to insufficient blood flow.) A combination of two separate phenomena are believed to explain the mechanism by which the ischemia test of the present invention works. First, it is believed that the localized acidosis which occurs during an ischemic event generates free radicals which alter albumin's N-terminus; thus, by detecting and quantifying the existence of altered albumin, ischemia can be detected and quantified.

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Second, the acidotic environment present during ischemia results in-the-release of bound copper (from ceruloplasmin and other copper-containing proteins) which is immediately taken up by albumin. The bound copper also alters the N-terminus of albumin. (Not only does the presence of the complexed copper effectively "alter" the

5   N-terminus, the metal ion damages the protein structure on binding.) Thus, by detecting and quantifying the existence of altered albumin, and/or the copper-albumin complexes, ischemia can be detected and quantified.

The details of the first mechanism are believed to be as follows. In the event of an oxygen insufficiency, cells convert to anaerobic metabolism, which depletes

10 ATP, resulting in localized acidosis and lowered pH, and causing a breakdown in the energy cycle (ATP cycle). Cellular pumps that keep calcium against the gradient are fueled by energy from the ATP cycle. With ATP depletion, the pumps cease to function and cause an influx of calcium into the cell. The excess intracellular calcium activates calcium-dependent proteases (calpain, calmodulin), which in turn cleave

15 segments of xanthine dehydrogenase, transforming the segments into xanthine oxidase. The enzymes involved in this process are membrane-bound and exposed to the outside of the cell, and are thus in contact with circulating blood. Xanthine oxidase generates superoxide free radicals in the presence of hypoxanthine and oxygen. Superoxide dismutase dismutates the oxygen free radicals, turning them into

20 hydrogen peroxide. In the presence of metals such as copper and iron which are found in blood, hydrogen peroxide causes hydroxyl free radicals to be formed. Hydroxyl free radicals in turn cause damage to cells and human tissue. One of the substances damaged by free radicals is the protein albumin, a circulating protein in human blood; specifically believed to be damaged is the N-terminus of albumin, resulting in the

25 albumin N-terminal derivatives.

Human serum albumin is the most abundant protein in blood (40g/l) and the major protein produced by the liver. Many other body fluids also contain albumin. The main biological function of albumin is believed to be regulation of the colloidal osmotic pressure of blood. The amino acid and structure of human albumin have been

30 determined. Specifically, human albumin is a single polypeptide chain consisting of

585 amino acids folded into three homologous domains with one free sulfhydryl group on residue # 34. The specific amino acid content of human albumin is:

Residues:	Asp	Asn	Thr	Ser	Glu	Gln	Pro	Gly	Ala	Cys	Val	Met	Ile	Leu	Tyr	Phe	His	Lys	Trp	Arg
Number	39	15	30	22	60	23	25	12	63	35	39	6	8	61	18	30	16	58	1	23

5   In the first embodiment of the present invention, an excess of metal (e.g., cobalt) ions are introduced into a (purified) albumin sample obtained from a patient serum, plasma, fluid or tissue sample (this embodiment is hereafter referred to as the "excess metal embodiment"). In normal (non-ischemic) patients, cobalt will bind to one or more amino acid chains on the N-terminus of albumin. In ischemic patients,

10   however, most likely due to the alteration of the binding site of the N-terminus, cobalt binding to albumin is reduced. Accordingly, the occurrence or non-occurrence of an ischemic state can be detected by the presence and quantity of bound or unbound cobalt. Measurement of cobalt can be conducted by atomic absorption, infrared spectroscopy, high-performance liquid chromatography ("HPLC") or other standard or

15   non-standard methods, including radioactive immunoassay techniques.

The details of the second mechanism are believed to be as follows. Ceruloplasmin is a circulating protein which binds copper; approximately ninety-percent of the in vivo copper (copper is abundant in blood, with concentrations comparable to iron) will be bound to ceruloplasmin. The remainder is in other bound

20   forms; almost no free copper exists in circulating blood. In acidic conditions and reduced oxygen conditions, such as happens during ischemia, ceruloplasmin releases some of its bound copper. The released copper is taken up by albumin. Copper and cobalt both bind to albumin at the same site within the N-terminus. Thus, the bound endogenous copper, present during ischemia, blocks cobalt from binding to albumin.

25   The decrease in cobalt binding capacity of circulating albumin can be measured and quantified as a means for detecting and quantifying the presence of an ischemic event.

The excess metal embodiment of the present invention comprises a method for detecting the occurrence or non-occurrence of an ischemic event in a patient comprising the steps of: (a) contacting a biological sample containing albumin of

said patient with an excess quantity of a metal ion salt, said metal ion capable of binding to the N-terminus of naturally occurring human albumin, to form a mixture containing bound metal ions and unbound metal ions, (b) determining the amount of bound metal ions, and (c) correlating the amount of bound metal ions to a known

5   value to determine the occurrence or non-occurrence of an ischemic event. In this method, said excess quantity of metal ion salt may comprise a predetermined quantity and the quantity of unbound metal ions may be detected to determine the amount of bound metal ions. Additionally, the compound selected from the group consisting of Asp-Ala-His-Lys-R, wherein R is any chemical group capable of being detected when

10   bound to a metal capable of binding to the N-terminus of naturally occurring human albumin, may be utilized to facilitate detection.

This method uses samples of serum or plasma, or purified albumin. Preferred embodiments also include use of a metal ion salt comprising a salt of a transition metal ion of Groups 1b-7b or 8 of the Periodic Table of the elements, a metal selected

15   from the group consisting of V, As, Co, Cu Sb, Cr, Mo, Mn, Ba, Zn, Ni, Hg, Cd, Fe, Pb, Au and Ag. Also preferred, is detection of the amount of bound metal ions (or, in the case where the excess quantity of metal ion salt is a predetermined quantity, detection of the quantity of unbound metal ions) by atomic absorption or atomic emission spectroscopy or immunological assay. These detection mechanisms are also

20   preferred for determination of the quantity of the compound Asp-Ala-His-Lys-R which is complexed with the metal ion salt in order to detect the quantity of unbound metal ions. A preferred method for conducting said immunological assay is using an antibody specific to an antigen comprising the compound Asp-Ala-His-Lys-R, wherein R is said metal ion.

25   Where the metal employed in the above excess metal embodiment is nickel, another preferred detection method is nuclear magnetic resonance (NMR). It has been observed that addition of Ni ion gives a sharp diamagnetic ^{1}H-NMR spectrum for the resonances of the first three amino acids (Asp-Ala-His) of the albumin N-terminus octapeptide. While Co ion can also induce changes in the NMR spectrum of the first

30   three amino acids of albumin, it induces paramagnetism at the binding site, resulting

in broadening of the resonances associated with the first three residues. Thus, the diamagnetic nature of the nickel complex makes it more amenable for NMR studies.

The excess metal embodiment of the present invention also includes a colorimetric method of detecting the occurrence or non-occurrence of an ischemic event in a patient comprising the steps of: (a) contacting a biological sample containing albumin of said patient with a predetermined excess quantity of a salt of a metal selected from the group consisting of V, As, Co, Cu, Sb, Cr, Mo, Mn, Ba, Zn, Ni, Hg, Cd, Fe, Pb, Au and Ag, to form a mixture containing bound metal ions and unbound metal ions, (b) contacting said mixture with an aqueous color forming compound solution to form a colored solution, wherein said compound is capable of forming color when bound to said unbound metal ion, (c) determining the color intensity of said colored solution to detect the presence of unbound metal ions to provide a measure of bound metal ions, and (d) correlating the amount of bound metal ions to a known value to determine the occurrence or non-occurrence of an ischemic event. Preferred embodiments of this method include the additional step of diluting said colored solution with an aqueous solution isosmotic with blood serum or plasma prior to step (c). Also preferred are: using ferrozine as the color forming compound, and, alternatively, using the compound Asp-Ala-His-Lys-R, wherein R is any group capable of forming color when bound to said metal ion as the aqueous color forming compound. Conducting steps (b) and (c) in a pH range of 7 to 9 is preferred. Further, conducting steps (b) and (c) using a spectrophotometer is preferred. Preferred samples in this method include serum, plasma, or purified albumin and a preferred metal ion salt is cobalt.

Another embodiment is based on the endogenous copper mechanism discussed above. This embodiment involves a method for detecting the occurrence or non-occurrence of an ischemic state in a patient comprising the steps of: (a) detecting the amount of endogenous copper ions present in a purified albumin sample of said patient, and (b) correlating the quantity of copper ions present with a known value to determine the occurrence or non-occurrence of an ischemic event. Preferred methods for detection of the amount of copper ions present in the purified albumin sample are

by atomic absorption, atomic emission spectroscopy and immunological assay. A preferred method of conducting said immunological assay uses an antibody specific to an antigen comprising the compound Asp-Ala-His-Lys-R, wherein R is copper. This embodiment is referred to as the endogenous copper method.

5   Another embodiment of the subject invention is also based on the first mechanism described above. The free radicals released during an ischemic event damage the N-terminus of albumin by causing the cleavage of up to four N-terminal amino acid residues, and possibly may induce acetylation of the N-terminus. The resulting albumin derivatives lack the capacity to bind to metal ions such as cobalt

10 ion. In the subject embodiment, an ischemic event is diagnosed by detecting the albumin derivatives that cannot bind metal ion. For this reason, the subject embodiment is referred to herein as the "derivative embodiment."

     As is reported in the Examples, albumin having an acetylated terminal Asp or lacking four, three, two or even one N-terminal amino acid have been found to lack

15 the capacity to bind to cobalt ion. It has been observed that albumin derivatives lacking four, three, two or one N-terminal amino acids are present in the serum or patients with ischemia.

     The derivative embodiment of the subject invention comprises a method of detecting or measuring an ischemic event in a patient by: (a) contacting a patient

20 sample comprising naturally-occurring albumin and optionally albumin N-terminal derivatives with an excess quantity of metal ion that binds to the N-terminus of naturally-occurring albumin, whereby albumin-metal complexes are formed; (b) partitioning the complexes from said derivatives, if any; (c) measuring at least one of said derivatives, if any; and (d) comparing said measured derivative to a known value,

25 whereby the ischemic event may be detected or measured.

     The derivative embodiment method can be practiced with a metal ion salt that is a salt of a transition metal ion of Groups 1b-7b or 8 of the Periodic Table of the Element. Preferably, the metal ion salt is a salt of a metal selected from the group consisting of V, As, Co, Sb, Cr, Mo, Mn, Ba, Zn, Ni, Hg, Cd, Fe, Pb, Au and Ag.

30 Most preferred is that the metal ion is Ni or Co. The minimum incubation period for

metal ion and albumin is at least 4-5 minutes, and preferably 10 minutes, i.e., an amount of time sufficient for equilibrium to be reached. It is also preferred that heparin be added to the sample prior to the addition of the excess quantity of metal ion.

The partitioning step of the derivative embodiment method can be carried out in two ways. It can be effected by having the excess metal ion of step (a) bound to a solid support such that the resulting albumin-metal complexes are retained on the solid support, permitting the elution separation of the albumin N-terminal derivatives. Alternatively, a solution of excess metal ion can be added to the patient sample, permitting the albumin-metal complexes to form, and the partitioning can be effected by contacting the complexes with antibodies to the metal-albumin complex that are bound to a solid support.

Thus, in one aspect, the derivative embodiment involves a method comprising: (a) contacting a patient sample comprising naturally-occurring albumin and optionally albumin N-terminal derivatives with an excess quantity of a metal ion bound to a solid support, whereby the metal ion binds to the N-terminus of naturally-occurring albumin, forming metal-albumin complexes; (b) separating the complexes from said derivatives, if any; (c) measuring at least one of said derivatives, if any; and (d) comparing said measured derivative to a known value, whereby the ischemic event may be detected or measured. It is preferred that the solid support of step (a) be a diacetate or a phosphonate matrix. It is also preferred that the metal ion used in step (a) be nickel ion. It is further preferred that copper ion not be used in this method as it is likely to demonstrate non-specific binding to albumin thiol groups (located outside the N-terminus), possibly generating false negative results.

Metal affinity chromatography methods useful in this embodiment are within the skill in the art. For example, resins for separating proteins (including albumin) using metal affinity chromatography are described in U.S. Pat. Nos. 4,569,794; 5,169,936; and 5,656,729.

In another aspect, the derivative embodiment involves a method comprising: (a) contacting a patient sample comprising naturally-occurring albumin and optionally

albumin N-terminal derivatives with an excess of a metal salt, whereby a metal-albumin complex is formed; (b) contacting the mixture of step (a) with an antibody to said complex, said antibody being bound to a solid support; (c) separating the complex from said N-terminal derivatives, if any; (d) measuring the amount of at least one N-terminal derivative, if any; and (e) comparing the measured N-terminal derivative to a known value, whereby an ischemic event may be detected or measured. In this aspect, it is preferred that the metal ion be cobalt ion.

The step of measuring the albumin N-terminal derivatives can be carried out using antibodies (monoclonal or polyclonal) to the derivatives. The antibodies can be directed to one or more of the N-terminal epitopes for each derivative. Thus, one or more antibodies directed to one or more N-terminal epitopes may be used to measure the derivatives. Additionally, measuring can be accomplished by employing an antibody(ies) to albumin non-N-terminal epitopes. Because the partitioning step has removed all naturally-occurring albumin, any remaining albumin will be an N-terminal derivative. Antibodies used in the measuring step are labeled, preferably with an enzyme or a fluorescent label or by other methods known in the art.

The derivative embodiment methods can be carried out using kits having components adapted to provide the reactants or reagents and carry out the process steps. Where the derivative embodiment method involves excess metal ion bound to a solid support, the kit illustrated in Figure 1 can be employed. Referring to Figure 1, the diagnostic kit 20 is constructed of an upper plate 1 and lower plate 3. The lower plate 3 has 1-2 elongated solid supports 6 (e.g., nitrocellulose) with a sample application filter 4 upon which a patient sample is applied through sample port 2. The filter 4 and port 2 may be positioned such that the filter 4 is common or shared by both elongated solid supports 6. The filter 4 removes cells (red and white blood cells, platelets, etc.), permitting plasma to flow through to supports 6. The patient sample migrates from the filter at the first end of each of the elongated solid supports 6 to the second ends at the end of process indicators 18. The first solid support 6 provides a test function and the second provides a control function. The solid support providing a test function has an area 8 of immobilized metal ion to which naturally-occurring

albumin binds. The albumin N-terminal derivatives continue to migrate down the solid support 6 to an area 10 containing ligand. In preferred embodiments, the ligands at area 10 are antibodies to albumin N-terminal derivatives and/or antibodies to naturally-occurring albumin. An antibody to naturally-occurring albumin may be

5   used at area 10 provided it is directed to an epitope that is not located at the N-terminus of naturally-occurring albumin, so that it may bind to the derivatives. An antibody at area 10 to an albumin N-terminal derivative refers to an antibody directed to an N-terminal epitope of the derivative, such that the antibody is specific (i.e., recognizes only) the particular albumin N-terminal derivative. An advantage of

10   including antibodies to albumin N-terminal derivatives at area 10 is that the amount of each or all N-terminal derivatives can be measured. Measurement of each derivative may permit a more accurate assessment of the degree and timing of the ischemic event. For example, a relatively higher concentration of the derivative lacking four N-terminal amino acids may reflect a greater degree or a longer duration of ischemia

15   than a second sample where another derivative (e.g., albumin lacking only its N-terminal Asp residue) is more prevalent. Although the relative order of appearance of each derivative during the course of an ischemic event has not yet been determined, it will be possible to do so upon correlation of derivatives observed in patient samples with clinical observations of patients from whom the samples have been derived.

20   In the control (second) elongated solid support 6, an area 11 containing ligand to albumin is provided to detect all albumin, naturally-occurring or N-terminal derivatives, in the sample. Thus, the antibody at area 11 is directed to an albumin epitope that is not located at the N-terminus of albumin. The antibody or antibody mixture at areas 10 and 11 should be the same for control purposes.

25   The test and control results can be observed through ports 12 and 14, respectively. The binding of albumin or albumin N-terminal derivatives to antibody is detected by methods known in the art such as sandwich assays, enzyme assays or color indicators. For example, a labeled antibody may be added through ports 12 and 14 to bind to any albumin that is bound to antibody attached to areas 10 and 11. The

30   label on the added antibody may be, for example, alkaline phosphatase, a commonly

used reporter enzyme which reacts with synthetic substrates such as 1,2-dioxetane or

p-nitrophenylphosphate to yield detectable products. Alternatively, a protein coloring

reagent such as bromo cresol purple or bromo cresol green may be present in areas 10

and 11 or added through ports 12 and 14.

5   Finally, an end of process indicator 18 at the second end of each elongated

solid support 6 may be employed to assure completion of the test, i.e., that a sufficient

volume of biological sample has passed down each elongated solid support 6 for the

test to be completed. Suitable end of process indicators 18 include pH indicators and

conductance indicators as is known in the art.

10   The kit illustrated in Figure 1 can also be used where the derivative

embodiment method employs a solid-support bound antibody to the albumin-metal

complex. Referring again to Figure 1, the patient sample is first mixed with excess

metal ion aqueous solution, whereby naturally-occurring albumin-metal complexes

are formed, and then applied to the filter 4 at the first end of the elongated solid

15   supports 6. As the sample migrates down the test (first) elongated solid support 6, it

encounters area 8 between the first and second ends which has immobilized antibody

to the albumin-metal complex. The albumin-metal complex binds to area 8, and the

N-terminal derivatives continue migration to area 10 containing ligand to albumin

which is proximate the second end. The ligand at area 10 can be an antibody directed

20   to an albumin epitope that is not located at the naturally-occurring N-terminus, or can

be antibodies to derivative N-terminal epitopes. An end of process indicator 18 can

also be present at the second end of the first elongated solid support. A second or

control elongated solid support 6 can also be present in the kit 20 with an area 11

having immobilized antibody to the albumin located between the first and second

25   ends.

          The subject invention provides additional kit embodiments suitable for the

derivative embodiment method employing the solid support bound antibody to

albumin-metal complex. Referring now to Figure 2, a kit 40 is provided containing a

solid support disk or circle 28 having a centrally located sample application filter 30

30   for application of a patient sample that has been mixed with excess metal ion,

whereby naturally-occurring albumin-metal complexes have been formed. The circular filter is surrounded by an inner concentric ring divided into a test half 32 which contains ligand (e.g., monoclonal antibody) to albumin-metal complexes, and a control half 34 which contain no ligand. Beyond the inner concentric ring is an outer

5 concentric ring divided into a test half 38 and a control half 36, both of which contain ligand to albumin. In area 36, ligand is provided that detects all albumin, naturally-occurring or N-terminal derivatives, in the sample. Thus, the antibody at area 36 is directed to an albumin epitope that is not located at the N-terminus of naturally-occurring albumin. In area 38, ligand to naturally-occurring albumin and/or to

10 albumin N-terminal derivatives is likewise provided. Again, for control purposes, the antibody or antibody mixture in areas 36 and 38 should be the same.

As the patient sample radiates from the filter 30, the albumin-metal complexes bind to antibody to complexes in area 32. Filtrate from area 32 passes into area 38, where albumin N-terminal derivatives bind to antibody. Likewise, as patient sample

15 radiates through area 34 of the control half and into area 38, all albumin present (naturally-occurring and derivative) binds to antibody present in area 36. The amount of albumin or albumin derivatives bound in area 38 is compared to a known value to determine whether an ischemic event has occurred. The amount of albumin or derivatives in area 38 can also be compared to a scale of known values, such as a color

20 scale, to determine the degree of the ischemic event. The amount of albumin or derivatives bound in area 38 is determined by methods known in the art including sandwich assays, enzyme assays or protein color reagents.

As can be appreciated by those skilled in the art, the embodiment in Figure 2 can also be readily adapted to the derivative embodiment method in which metal ion

25 is bound to the solid support. Specifically, the solid support area 32 would have metal ion bound thereto rather than antibody to albumin-metal complex.

Figure 3 illustrates another kit 60 suitable for the derivative embodiment method employing the solid support bound antibody to albumin-metal complex. The kit 60 comprises a circular solid support 56 with a centrally located sample

30 application filter 50. The filter 50 is surrounded by a concen

20

into two semi-circles. The control semi-circle contains an area 54 containing ligand to naturally-occurring albumin and albumin derivatives, preferably an antibody directed to an albumin epitope not located at the N-terminus of naturally-occurring albumin. The test semi-circle contains an area 52 containing ligand to albumin-metal complex.

5   Thus, after a patient sample is mixed with an excess metal ion solution, whereby albumin-metal complexes are formed, it is applied to filter 50 from which it radiates to area 52, where the albumin-metal complexes bind to the ligand. In the control semi-circle, the patient sample radiates and the naturally-occurring albumin (complexes) and derivatives bind to the ligand in area 54. The ligand in area 54 is

10   preferably a monoclonal or polyclonal antibody directed to a non-N-terminal epitope of naturally-occurring albumin. By comparing the amount of total albumin and derivatives bound to area 54 to the amount of albumin-metal complexes bound to area 52, the amount of albumin derivatives can be calculated or estimated, and an ischemic event detected or measured. The albumin or derivatives bound to antibodies on each

15   area (52 or 54) can be detected or measured by methods known in the art including sandwich assays, enzyme assays and protein color assays.

Figure 3 can likewise be adapted to be useful in the derivative embodiment method in which metal ion is bound to the solid support, i.e., where metal ion is immobilized in area 52.

20   As is discussed above, a variety of antibodies are employed in the various embodiments of the subject invention. In the excess metal, endogenous copper and derivative embodiments, antibodies to albumin-metal complexes are employed. Patient antibodies specific to the albumin-metal (cobalt and nickel) complexes (including the N-terminal epitope) have been identified in occupational studies

25   (Nieboer et al. (1984) Br. J. Ind. Med. 41:56-63; Shirakawa et al. (1992) Clin. Exp. Allergy 22:213-218; Shirakawa et al. (1990) Thorax 45:267-271; Shirakawa et al. (1988) Clin. Allergy 18:451-460; and Dolovich et al. (1984) Br. J. Ind. Med. 41:51-55). Additionally, rabbit antibodies to human albumin-metal complexes have also been generated (Veien et al. (1979) Contact Dermatitis 5:378-382). Therefore,

antibodies to albumin-metal complexes for use in the subject methods either already exist in the art or would be readily obtainable using known methods.

In addition to the foregoing antibodies, the derivative embodiment may also use antibodies to one or more of the albumin N-terminal derivatives. As is set forth in the Examples, it has been found that the albumin derivatives that lack four, three, two and even one N-terminal amino acid have lost the capacity to bind to cobalt. Additionally, full-length albumin that has been acetylated at its Asp residue also cannot bind to cobalt. As is appreciated by the skilled artisan, antibodies that are specific to (i.e., recognize only) each of these derivatives can be obtained using known monoclonal antibody technology. Adjuvants such as KLH may be used to enhance immunogenicity.

Applications, embodiments and methods of the present invention comprising one or more of the aforementioned methods of the present invention include: A method for ruling-out the existence of ischemia in a patient, comprising application of any of the aforementioned methods, including application of any of the subject methods wherein said patient possesses one or more cardiac risk factors, said cardiac risk factors being selected from the group consisting of: age greater than 50, history of smoking, diabetes mellitus, obesity, high blood pressure, high cholesterol, and strong family history of cardiac disease. A variant thereof, comprises subjecting the patient to an exercise treadmill test followed by a second application of the same method, followed by a comparison of the results of the two applications. Comparison of the before and after ischemia diagnostic tests will reveal whether the ischemic event is induced only under the elevated metabolic conditions of exercise. This method may be used to detect the existence of ischemia provoked by exercise in an otherwise asymptomatic patient.

Other embodiments, applications and variants of the present invention include a method for ruling-out the occurrence of an temporally-limited ischemic event in a patient comprising application of any of the subject diagnostic methods; a method of detecting the existence of ischemia in an asymptomatic patient comprising application of any of the subject diagnostic methods; a method for the evaluation of patients

suffering from stroke-like signs to determine the occurrence or non-occurrence of a stroke, comprising application of any of the subject diagnostic methods; a method for distinguishing between the occurrence of an ischemic stroke and a hemorrhagic stroke, comprising application of any of the subject diagnostic methods; and a method

5   for assessing the efficacy of an angioplasty procedure, comprising application of any of the subject diagnostic methods.

The present invention also provides a method for evaluation of a patient presenting with angina or angina-like symptoms to detect the occurrence or non-occurrence of a myocardial infarction, comprising application of any of the subject

10   diagnostic methods and application of an electrocardiographic test, followed by correlation of the results of the application of the diagnostic method with the results of the electrocardiographic test to determine the occurrence or non-occurrence of a myocardial infarction. Preferred electrocardiographic tests are E.C.G., E.K.G. and S.A.E.C.G. tests.

15   Another method of the present invention is a method for supplementing electrocardiographic results to determine the occurrence or non-occurrence of an ischemic event, comprising application of any of the subject diagnostic methods and application of an electrocardiographic test, followed by correlation of the results of application of the diagnostic method with the results of said electrocardiographic test

20   to determine the occurrence or non-occurrence of an ischemic event. A variant thereof, comprises application of the method wherein said patient is undergoing surgery.

A further method of the present invention is a method for comparing levels of ischemia in patients at rest and during exercise is also taught by the present invention,

25   comprising application of the following steps at designated times: (a) application of any of the subject diagnostic methods at a first designated time, (b) administration of an exercise treadmill test followed by a second application of the same diagnostic method employed in step (a), (c) comparing the results of the application of the diagnostic method prior to administration of the exercise treadmill test with the results

30   of the application of the diagnostic method after administration of the exercise

treadmill test, and (d) repeating steps (a) through (c) at additional designated times
wherein, results obtained at designated time are compared. This embodiment may be
used to evaluate patients with known or suspected ischemic conditions, to assess the
patency of an in-situ coronary stent and to assess the efficacy of an angioplasty

5   procedure. Preferred designated time intervals are three months, six months or one
year.

The present invention also teaches a method for assessing the efficacy of
thrombolytic drug therapy, comprising the application of any of the subject diagnostic
methods; and a method for detecting in a pregnant woman the occurrence of placental

10   insufficiency, comprising application of any of the subject diagnostic methods.

The subject invention also includes calibration standards which have known
molar ratios of albumin and metal and are useful in calibrating analyzers or kits that
employ the subject methods. In one embodiment, the calibrator compositions are
standards to be used to generate standard curves for calibration of clinical chemistry

15   analyzers such as the Beckman CX-5™, Roche Cobas Mira™ and Dimension XL™.
These analyzers can each detect or measure ischemic events based on the colorimetric
version of the excess metal embodiment described herein. The calibrator
compositions can also be used to calibrate analyzers such as atomic absorbance or
atomic emission spectrophotometers. The calibrator compositions have preselected or

20   predetermined ratios of naturally-occurring albumin and metal ion. In preferred
embodiments, the albumin is human, the solution is buffered (e.g., Tris or HEPES),
the pH is about 7-8, and the metal is divalent and is selected from the group consisting
of cobalt, nickel and copper. Aliquots of these calibrators, under specific conditions,
produce a defined absorbance at 470-500 nm, i.e., a standard curve.

25   The albumin that is used in the calibrators is substantially all naturally-
occurring. By "substantially all," it is meant that at least 70%, and with increasing
preference, at least 80%, 90% and 95% by weight, of the albumin is naturally-
occurring. Without wishing to be bound by theory, it is believed that when the
calibrator compositions are placed in solution, the metal ion becomes primarily bound

to the N-terminus of the albumin, although it is possible that a minor amount of metal ion can be bound to thiol or other groups located on the albumin.

The calibrators are typically manufactured by starting with initial concentrated solutions of albumin and metal salt, and then mixing these concentrates in defined ratios to obtain desired molar ratios of albumin and metal concentrations in the resulting calibrator solutions.

To generate the standard curve for the colorimetry-type analyzers, each of the calibrator solutions is mixed with a known, constant amount of excess metal salt and excess coloring reagent as described herein. Thereafter, absorbance is measured at 500 nm and blocked albumin is plotted against absorbance. Because the amount of metal originally present in the calibrator solution and the excess metal salt added are both known, the absorbance, which is associated with the excess metal ion that did not bind to albumin, can be correlated with degree of N-terminal blockage of albumin originally present in the calibrator solution. As the degree of N-terminal blockage, i.e., percentage of original metal concentration, in the calibrator solution increases, the absorbance due to excess metal ion that does not bind to albumin also increases. The relationship is linear.

To generate the standard curve for the atomic absorbance or atomic emission spectrophotometer, the calibrator solutions are applied to the analyzer. The absorbance is plotted against the original metal concentration present in each calibrator to generate the standard curve.

Thus, the calibrator solutions are designed and intended to mimic ischemic patient samples in reflecting a range of albumin that is already bound to metal ion and is unavailable for binding to exogenously added metal ion. For example, a calibrator solution that has 75% of its albumin blocked with Cu at its N-terminus has only 25% of its albumin available for binding to exogenous, excess Co. After addition of coloring reagent to react with unreacted Co, absorbance at 500 nm will be much greater than that which would be observed for a calibrator solution that is only 25% blocked with Cu at its N-terminus.

For quality control purposes, the characteristics of the calibrators can be verified by:

1.   measuring their metal to albumin ratio; metal can be measured by atomic absorption, and albumin can be measured by bromo cresol green (BCG) assay;

2.   using radioactive Co^{57} albumin binding assay employing a Sepharose column;

3.   measuring the absorbance of the calibrators at the appropriate wavelength over time; and

4.   measuring the absorbance of mixtures of calibrator solutions and excess cobalt plus coloring reagent, such as dithiothreitol (DTT).

A greater understanding of the present invention and of its many advantages may be had from the following examples, given by way of illustration. The following examples are illustrative of some of the methods, applications, embodiments and variants of the present invention. They are, of course, not to be considered in any way limitative of the invention. Numerous changes and modification can be made with respect to the invention.

EXAMPLE 1
Sample Handling Procedures for Ischemia Testing

The samples which were used in the present invention were obtained from a variety of tissues or fluid samples taken from a patient, or from commercial vendor sources. Appropriate fluid samples included whole blood, venous blood, arterial blood, blood serum, plasma, as well as other body fluids such as amniotic fluid, lymph, cerebrospinal fluid, saliva, etc. The samples were obtained by well known conventional biopsy and fluid sampling techniques. Preferred samples were blood plasma and serum and purified albumin. Purified albumin was isolated from the serum by any of the known techniques, including electrophoresis, ion exchange, affinity chromatography, gel filtration, etc.

Blood samples were taken using Universal Precautions. Peripheral venipuncture was performed with the tourniquet on less than 30 seconds (contralateral

26

arm from any IV fluids). Blood is drawn directly into two 10 cc Becton Dickinson
Vacutainer® Sodium-Heparinized tubes and was gently inverted once to mix. If an
IV port was in use, the blood was collected (after a discard sample was drawn
equivalent to the dead space of usually 5 cc) into a plain syringe and dripped gently

5   down the side of two 10 cc Becton Dickinson Vacutainer® brand tubes and gently
inverted once to mix. Blood was also collected directly from the Vacutainer® tubes
with special administration sets with a reservoir system that does not require a discard
sample. These systems allow a draw to be taken proximal to the reservoir.

Plasma tubes were centrifuged within 2 hours of the draw. (Note, collected

10   serum was clotted between 30-120 minutes at room temperature (RT) before
centrifugation. The inside of the serum tube was ringed with a wooden applicator to
release the clot from the glass before centrifugation. If the subject was taking anti-
coagulants or had a blood clotting dysfunction, the sample was allowed to clot longer
than 60 minutes, between 90-120 minutes was best.) The tubes were centrifuged for

15   10 minutes at RT at 1100g (<1300g). Collected samples were pooled in a plastic
conical tube and inverted once to mix.

If the sample was not used within 4 hours of centrifugation, the sample was
frozen. Alternatively, separated serum was refrigerated at 4° C until tested, but was
tested within 8 hours (storage over 24 hours may have resulted in degradation of the

20   sample). "Stat" results (obtained within 1 hour of completion of centrifugation step)
were preferred. The following percent differences for the ischemia test were
measured using plasma and serum samples ≤ 8 hours and ≤ 24 hours after collection.
Delayed test results were compared to stat test results on the same patient sample and
the mean percent differences (and standard deviations) were as given below:

25

Storage and Delayed Testing Data for the Ischemia Test

		≤ 8 hrs. vs. stat		≤ 24 hr. vs. stat*
Plasma (stored at room temp)	n % diff S.D.	20 -5.3% .094	n % diff S.D.	23 -4.8% .090
Plasma (stored at 4° C)	n % diff S.D.	18 1.7% .070	n % diff S.D.	40 1.0% .094
Serum (stored at room temp)	n % diff S.D.	16 -12.8% .157	(not enough samples)	
Serum (stored at 4° C)	n % diff S.D.	14 -7.3% .040	n % diff S.D.	24 -2.7% .210

* ≤ 24 hr. test results given here are a total that include the ≤ 8 hr. test sample results.

EXAMPLE 2
Test Method for Detecting Occurrence of Ischemic Event Using Cobalt Binding

The ischemia test (cobalt version) was run as follows: 200 µl of patient sera was added to each of two tubes each containing 50 µl 0.1% $CoCl_2 \bullet 6H_2O$. The mixture was allowed to react at room temperature (18-25° C), or higher, for 5 or more minutes. Thereafter 50 µl 0.01 M dithiothreitol (DTT) was added to one of the two tubes (the "test tube") and 50 µl 0.9% NaCl was added to the second tube (the "background tube"). After two minutes, 1 ml 0.9% NaCl was added to both tubes. A470 spectroscopy measurements were taken of the two tubes. The ischemia test was considered positive if the optical density was greater than or equal to .400 OD (or alternatively a clinically derived cut-off) using a spectrophotometer at OD 470nm.

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Equivalent materials which may be used as alternatives include any of the transition metals. Ferrozine or other compounds with an affinity to cobalt can be substituted for DTT and/or any cobalt or metal coloring reagent. $CoCl_2 \bullet 6H_2O$, for instance, can be utilized. The optimal range for cobalt binding to albumin is from pH

5   7 to pH 9, with a range of pH 7.4-8.9 being most preferred; pH 9 is optimal for cobalt interaction with the color reagent. The amount of serum sample can also vary, as can the amounts of $CoCl_2 \bullet 6H_2O$ and DTT and ferrozine. Critical, however, is that the amount of cobalt used be in excess of the amount of albumin and that the DTT or ferrozine be in excess of the cobalt.

10

EXAMPLE 3
Test Method For Detecting Occurrence of Ischemic Event Using Measurement of Copper

15   Albumin was purified from .2 cc of human serum or plasma using an ion exchange method to produce approximately 8 mg of purified albumin. A buffer having a pH in the range of 7 to 9 was added. The amount of copper present in the sample was then measured by direct spectrophotometric and potentiometric methods, or by any of several other known methods, including atomic absorption, infrared

20   spectroscopy, HPLC and other standard or non-standard methods, including radioactive tracer techniques. The proportion of copper to albumin can be then used as a measure of ischemia, the greater the proportion, the higher the ischemia value.

EXAMPLE 4
Test Method for Ruling-out The Existence of Ischemia in a Patient

25   The following protocol is designed to rule out ischemic conditions in healthy appearing patients who describe prior symptoms of occasional chest pain or shortness of breath.

First, a medical history (including a detailed history of the present and past

30   medical problems and risk factors for ischemic heart disease), physical exam, and vital signs are obtained. If the patient has any cardiac risk factor for ischemic heart disease (age > 50, smoking, diabetes mellitus, obesity, high blood pressure, elevated

low density lipoproteins, high cholesterol, and strong family history of cardiac disease), the physician is instructed to order a resting twelve-lead EKG and a chest x-ray. If the twelve-lead EKG shows evidence of an acute myocardial infarction (AMI), the patient is immediately transported to a hospital for intensive cardiac treatment. If the twelve-lead EKG does not show evidence of (AMI), the patient will be scheduled for an outpatient twelve-lead EKG exercise treadmill within the next few days. A blood sample should be drawn immediately before and again after the exercise treadmill test and the ischemia test run on each sample.

If the exercise treadmill test shows definite evidence of cardiac ischemia, usually seen by characteristic changes of the ST segments, dramatic abnormalities of pulse or blood pressure, or anginal chest pain, the patient should be treated for cardiac ischemia and referred to a cardiologist for possible coronary angiogram and angioplasty. If the exercise treadmill test does not show any evidence of cardiac ischemia, or the findings are equivocal, but the ischemia test is abnormal, the patient similarly should be treated for cardiac ischemia and referred to a cardiologist for possible coronary angiogram and angioplasty. (Absent the present invention, such patients with moderate to high cardiac risk factors would be referred to a cardiologist for further (typically invasive) cardiac testing).

If the exercise treadmill test does not show any evidence of ischemic heart disease, or the findings are equivocal, and the ischemia test is normal, the patient may be sent home with no evidence of cardiac ischemia. In comparison, prior to the present invention, in the case where the exercise treadmill test does not show any evidence of cardiac ischemia, or the findings are equivocal, patients with low risk for cardiac ischemia typically would not have any other tests ordered. In such cases, the physician is taking a calculated risk. It is well documented in the medical literature that at least 25 to 55 percent of patients (higher in females) will have some ischemic heart disease which is not found with routine exercise treadmill testing.

EXAMPLE 5
Test Method for Evaluating Patients with Angina to Rule-out the Occurrence of An Ischemic Event

In this study, clinical criteria (EKG changes, elevated cardiac enzymes or markers, positive thallium treadmill or positive angiogram) were used to determine the presence or absence of ischemia in patients presenting with chest pain. Ischemic patients were those with at least one clinical finding positive for ischemia. Normal patients were those for whom clinical findings were negative, as well as normal volunteers with no history or symptoms of cardiac or cerebral ischemia.

Blood samples were taken from 139 subjects who either presented to emergency departments of several hospitals with chest pain or normal volunteers. Blood was drawn into plain red top tubes and, after ten minutes, the clotted blood was centrifuged to separate the serum. Serum was refrigerated at 4° C until tested. If the sample would not be used within 4 hours of centrifugation, it was frozen, but in no case was testing delayed more than 3 days.

Samples were centrifuged for 5-10 minutes in an analytical centrifuge immediately before testing. 200 µl off each sample was aliquoted in triplicate with an additional tube to be used as a Blank (no DTT) control into borosilicate glass tubes. Also aliquoted was 200 µl of a Standard, such as Accutrol or HSA, in triplicate plus a Blank control. At 10 second intervals, 50.0 µl of 0.10% $CoCl_2$ (store working stock and stock at 4° C) was added to each tube. Solution was added to the sample, not glass, and tubes were "flicked" to mix.

After 10.0 minutes (starting with the first tube to which cobalt solution was added) an additional 50.0 µl of 0.9% NaCl was added to the two Blank tubes using the appropriate 10 second intervals. 50.0 µl of 0.01 M DTT was additionally added to the Plasma (not Blank) tubes in their appropriate 10 second intervals. Of note, it is preferred that DTT be made fresh weekly (6 mg per 4 ml H_2O) and stored at 4° C.

After 2 minutes (starting with the first tube to which cobalt solution was added) 1.0 ml of 0.9% NaCl solution was added to each tube, using the appropriate 10 second intervals. Tubes were agitated to mix. In the event that there were too many

tubes to finish the test tubes in 10 second intervals, reagents were added to the "Blank" tubes without timing.

The optical density of each sample set was read using the set's Blank to read absorbance at 470 nm. The cuvette was checked for air bubbles before reading and washed with H_2O between sets. The ischemia test was considered positive if the optical density was greater than or equal to .400 using the spectrophotometer at OD 470 nm.

The results of the ischemia test compared to the diagnosis determined by clinical criteria are as described in the chart below. Four false negatives and three false positives were reported.

Clinical Diagnosis		Ischemia Test	
		+	—
+	99	95	4
—	40	3	37

Study results demonstrated that the ischemia test marker has a higher value in patients with clinically diagnosed ischemia. The diagnostic accuracy of the ischemia test for the chest pain study was above 90 percent (sensitivity, 96.0%; specificity, 92.5%; predictive value, (+)96.9%; predictive value, (-) 90.2%).

EXAMPLE 6

Test Method For Evaluation of Patients Suffering From Chest Pain to Determine the Occurrence or Non-occurrence of a Myocardial Infarction

The following study is proposed to test the ability of the present invention to detect ischemia in the initial hours following the onset of chest discomfort suspicious for cardiac ischemia. The cobalt version of the test is used.

The patient population is limited to male or female persons, 30 years or older, who present to the Emergency Department with complaints of chest discomfort of less than four hours in duration for reasons independent of the study. Patients will be

excluded from the study if they meet any of the following criteria: (1) known
concurrent non-cardiac ischemic disease(s), including but not limited to transient
ischemic attacks, cerebral vascular accident, peripheral vascular disease, intermittent
claudication, bowel ischemia, and severe renal failure; (2) definite radiological
5   evidence of a cause of chest discomfort that is other than cardiac ischemia, such as,
but not limited to, pneumonia, pneumothorax, and pulmonary embolus; or (3) chest
discomfort temporally related to local trauma.

All standard evaluation and treatment appropriate for emergency department
patients with suspected cardiac ischemia will be followed at all times. The drawing of
10   blood for the study will not in any manner modify the standard treatment protocol.
Within these parameters, a pre-treatment evaluation will be conducted, which will
include documentation of all current medications, documentation of previous medical
history, EKG, laboratory and radiographic test results, and documentation of most
recent vital signs and a physical examination.

15   The study consists of drawing an extra blood sample at the time of admission
to the emergency department. Samples are collected from a catheter that is already in
place for intravenous access or alternatively by venipuncture. Collection and
administration of the ischemia test is as described in Example 5 herein.

20   EXAMPLE 7
Test Method For Detection of Ischemia in Patient at Rest and During Exercise

The primary objective of this trial was to employ and test the sensitivity of the
ischemia test at various time points, before, during and after an exercise thallium
25   treadmill test. Preliminary data has shown that the blood level of the ischemia test
(i.e., absorbance, cobalt excess metal embodiment) rises immediately after an
ischemic event. The purpose of this pilot investigation is to determine the magnitude
of this rise in level of the ischemia test during a test to define the presence or absence
of a cardiac ischemic event, said test being the exercise thallium treadmill test. While
30   it is possible that patients scheduled for exercise thallium treadmill test may have
already experienced an ischemic event, preliminary data indicates that a further,

significant decline in cobalt binding (and an increase in the serum absorbance or unbound metal ion) will occur if tissue ischemia is induced during the exercise thallium treadmill test.

Patients already scheduled for an exercise thallium treadmill test were asked to give their consent for participation which required two tubes of blood (20 cc's) to be drawn up to 5 (five) times before, during and after the exercise thallium treadmill test. Eligible patients consisted of patients who met all of the following criteria: (1) Age: 18 years or older; (2) Male or female; (3) able to provide written informed consent; and (4) referred for exercise thallium treadmill test for reasons independent of this investigation. Patients were excluded from participation in the study if they met any of the following criteria: (1) known concurrent non-cardiac ischemic disease including, but not limited to: transient ischemic attacks, cerebral vascular accident, acute myocardial infarction and intermittent claudication; (2) inability to complete the standard protocol for the exercise portion of the exercise thallium treadmill test; or (3) cardiac arrest during the exercise portion of the exercise thallium treadmill test.

Prior to administration of the exercise thallium treadmill test, a pretreatment evaluation was conducted which included documentation of all current medications, documentation of previous medical history, EKG, laboratory and radiographic test results, and documentation of most recent vital signs and physical examination.

The standard exercise thallium treadmill test procedure was followed at all times. In no instance was the drawing of the additional blood samples for the purpose of the study permitted to subject the patient to additional risk (beyond the drawing of blood), or to in any manner modify the treatment of the patient.

The "standard" exercise thallium treadmill test procedure comprised generally the following: The patient was brought to the exercise test room in a recently fasting state. After initial vital signs and recent history was recorded, the patient was connected to a twelve-lead EKG monitor, an intravenous line was established and the patient was instructed in the use of a treadmill. With the cardiologist in attendance, the patient walked on the treadmill according to the standard Bruce protocol: starting at a slow pace (approx. 1.7 mph) and gradually increasing both the percent grade

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(slope) of the treadmill and the walking speed at three minute intervals up to a maximum of 5.5 mph at 20° grade. Termination of the exercise portion on the exercise thallium treadmill test occurred at the discretion of the cardiologist based on patient symptoms, EKG abnormalities, or the attainment of ò 85% maximal heart rate.

5 With the patient near maximal effort on the treadmill, approximately 3 mCi of thallium[201] was injected intravenously while the patient continued to exercise for approximately one more minute. At the end of exercise, single photon emission computerized tomography (SPECT) was used to scan the patient's myocardium for any perfusion defects. Following recovery, between 2 and 4 hours after exercise, a

10 smaller amount of thallium[201] (approximately 1.5 mCi) was re-injected for repeat SPECT scan. EKG's and SPECT scans were analyzed for ischemic criteria. The SPECT scans may show fixed and reversible perfusion defects. The reversible perfusion defects indicate ischemia and the fixed defects indicate myocardial scarring.

The study consisted of drawing blood samples on 3 occasions during the

15 exercise thallium treadmill procedure. Two tubes of blood (approximately 4 teaspoons) were collected before the exercise test, immediately after exercise, and between 1 and 4 hours after exercise. Blood samples were collected from the catheter already in place for the exercise thallium treadmill procedure or alternatively by venipuncture. Note: Radiation Protection /Safety Considerations -- Blood drawn

20 following thallium[201] injection was routinely considered safe because the amount injected was approximately 3 mCi and, for all practical purposes, the dilution into the systemic circulation reduces the sample level to less than 0.67 nanoCi per cc.

Standard patient follow-up was conducted according to clinical practice. Patients who had subsequent coronary angiograms after being enrolled in this exercise

25 thallium treadmill test study had all resultant coronary angiogram information obtained recorded to verify the exercise thallium treadmill test results.

All clinical and research laboratory testing procedures were performed in a blinded fashion.

Of the 59 patients enrolled (plasma and serum samples tested by the ischemia test method), 11 patients were deleted because of one of the following reasons: a chronically occluded coronary artery and no sample collected later than one hour after exercise, a clinical history of exercise leg pain (claudication), hemolyzed baseline blood samples, patient did not continue with the exercise study or did not agree to further blood tests, patient received an exercycle thallium test instead of a treadmill thallium test and one patient whose chest pain was later determined to be due to pneumonia.

Of the remaining 48 patients, 23 had no history of known ischemic heart disease, 23 had prior ischemic heart disease requiring angioplasty or coronary artery bypass grafts and 2 had prior myocardial infarctions but did not receive angioplasty or coronary artery bypass grafts. In the subgroup of 23 patients with no prior history of ischemic heart disease (using a total outcome score of ≥ 9 and a $\geq 4.7\%$ increase in Ischemia Test values (i.e., absorbance associated with unbound excess metal ion) either one or three hours after exercise as positive for ischemia) there were 2 true positives, 15 true negatives, 6 false positives and 0 false negatives for a sensitivity of 100% and a specificity of 72%.

Using the same criteria for positive exercise thallium treadmill and Ischemia Test results, the entire 48 patients (including patients with and without a prior history of ischemic heart disease) had 6 true positives, 29 true negatives, 11 false positives and 2 false negatives for a sensitivity of 75% and a specificity of 73%.

Changing the positive criteria to a total thallium treadmill outcome score of $\geq$ 10 and a $\geq 5.4\%$ increase in Ischemia Test values one hour after exercise for the entire 48 patients (including patients with and without a prior history of ischemic heart disease) gave 3 true positives, 37 true negatives, 7 false positives and 1 false negative for a sensitivity of 75% and a specificity of 88%.

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EXAMPLE 8
Assessing Efficacy of an Angioplasty Procedure

Percutaneous transluminal coronary angioplasty ("PTCA"), also referred to as coronary artery balloon dilation or balloon angioplasty, is an established and effective therapy for some patients with coronary artery disease. PTCA is an invasive procedure in which a coronary artery is totally occluded for several minutes by inflation of a balloon. The inflated balloon creates transient but significant ischemia in the coronary artery distal to the balloon. The result, however, is a widening of a narrowed artery.

PTCA is regarded as a less traumatic and less expensive alternative to bypass surgery for some patients with coronary artery disease. However, in 25 to 30 percent of patients, the dilated segment of the artery renarrows within six months after the procedure. In these cases, either repeat PTCA or coronary artery bypass surgery is required. Additionally, complications from angioplasty occur in a small percentage of patients. Approximately, 1 to 3 percent of PTCA patients require emergency coronary bypass surgery following a complicated angioplasty procedure.

The present invention addresses both problems by providing a means for monitoring on-going angioplasty procedures and by providing a mechanism for monitoring the post-angioplasty status of patients.

Twenty-eight patients already scheduled for emergent or elective angioplasty had blood samples (20 ml) drawn just prior to undergoing PTCA ("baseline") at 6, 12 and 24 hours after the last balloon deflation, and three tubes (25ml) at 1 minute and 6 minutes after the last balloon deflation. Collection and administration of the test was as described in Example 5 herein. A detailed description of the angioplasty procedure was also recorded so the magnitude of 'downstream' ischemia could be estimated. This included catheter size, number of inflations, inflation pressure, duration of inflation, number of vessels involved and location.

The eligible patient population consisted of male or female patients who met all of the following criteria: (1) 18 years or older; (2) referred for PTCA for reasons independent of the study; (3) able to give written, informed consent; and (4) and did

not possess any of the exclusionary criteria. Patients were excluded if they met any of the following criteria: (1) patients who were to have PTCA performed with a perfusion catheter; (2) patients with known, concurrent ischemic disease including, but not limited to transient ischemic attacks, cerebral vascular accident, acute

5   myocardial infarction and intermittent claudication. Prior to PTCA, a pretreatment evaluation was conducted which included documentation of all concurrent medications and the taking of a blood sample for ischemia test administration and baseline (this occurred after the patient had been heparinized and the sheath placed).

The standard PTCA protocol was followed at all times. In no instance was the

10   drawing of the additional tubes of blood permitted to subject the patient to additional risk (beyond the drawing of the blood), or modify the standard protocol.

The "standard" PTCA protocol generally comprised the following: The patient was transported to the cardiac catheterization laboratory in the fasting state. The right groin draped and prepped in the usual sterile fashion. Local anesthesia was

15   administered consisting of 2% lidocaine injected subcutaneously and the right femoral artery entered using an 18 gauge needle, and an 8 French arterial sheath inserted over a guide wire using the modified Seldinger technique. Heparin, 3000 units, was administered I.V. Left coronary cineangiography was performed using Judkins left 4 and right 4 catheters, and left ventricular cineangiography performed using the

20   automated injection of 30 cc of radiocontrast material in the RAO projection. After review of the coronary angiography, PTCA was performed.

The diagnostic cardiac catheter was then removed from the femoral sheath and exchanged for a PTCA guiding catheter which was then positioned in the right or left coronary ostia. An additional bolus of intravenous heparin, 10,000 units, was

25   administered. A coronary guidewire, usually a 0.014 inch flexible tipped wire, was then advanced across the obstruction and positioned distally in the coronary artery. Over this guidewire, the balloon inflation system was inserted, usually consisting of a "monorail" type balloon dilation catheter. Sequential balloon inflations were made, with angiographic monitoring between inflations. The duration of the inflations

varied among operators, but averaged approximately 45 - 60 seconds, occasionally prolonged inflations between 3 and 15 minutes were performed.

When it was determined that adequate opening of the coronary stenosis had been achieved, the balloon catheter was fully withdrawn and coronary angiograms performed with and without the guidewire in position. If no further intervention was believed to be necessary, the sheath was then sewn into position and the patient transported to either the intensive care unit or observation unit. The sheath was removed after approximately 6 hours and firm pressure applied with a C clamp or manual pressure. The patient remained at bed rest for approximately 6 hours after sheath removal.

Standard patient follow up was conducted according to clinical practice.

As stated, sample collection and administration of the ischemia test occurred essentially as described in Example 5 herein. The test technician was masked to the time the PTCA sample was taken.

Compared to baseline, 26 of the 28 tested patients demonstrated increased ischemia values after balloon inflation. The remaining two patients registered false negatives, both of which started with baseline values above .400. The mean increase in the ischemia test value from baseline to balloon inflation was 15.2%. Of the 21 patients that had 5 hour samples tested, all but three demonstrated a decreased ischemia test value compared to that measured during balloon inflation. Study results demonstrated that the ischemia test marker rises almost immediately following controlled onset of ischemia during the angioplasty procedure. The rapid rise of the marker during balloon inflation and its descent over a five hour period correlated with the controlled start and stop of ischemia. The diagnostic accuracy of the study was 96 percent.

EXAMPLE 9
Evaluation of Post-Myocardial Infarction Patients

In a second study, three subsets of patients -- patients without acute myocardial infarction (NonAMI), patients with acute myocardial infarction (AMI),

and patients without AMI with significant collateral circulation (NonAMI collateral) --- all of whom were undergoing emergent or elective angioplasty had blood samples collected prior to PTCA, immediately after balloon deflation, 6 hours after the procedure, and 24 hours after the procedure. A total of 63 patients were tested. The standard PTCA protocol (as described in Example 8) was followed.

During PTCA, blood was drawn into a syringe and then transferred to sodium-heparinized tubes. Post PTCA samples were drawn into green top sodium-heparinized tubes. In all other regards, sample collection and administration of the ischemia test occurred essentially as described in Example 5 herein. The test technician was masked to the time the PTCA sample was taken.

The ischemia test was considered positive if it increased between baseline and immediately after balloon angioplasty. The results of the study showed a statistically significant rise (p=0.0001) in the ischemia test marker following balloon angioplasty and a return to baseline within 24 hours. The mean percent increase for all patients in the study was 9.4%. .

TIME POINT	N	MEAN	SD	MEAN DIFF FROM BASELINE	SD	MEAN % DIFF FROM BASELINE	SD	P-VALUE
Baseline	62	.354	.0424	.	.	.	.	.
Immed. post PTCA	63	.385	.0411	.0310	.0382	9.4%	.1178	.0001
6 hours post PTCA	57	.368	.0513	.0150	.0505	5.0%	.1507	.0167
24 hours post PTCA	43	.363	.0474	.0090	.0444	3.2%	.1312	.1221

% CHANGE FROM	WITH AMI			WITHOUT AMI			T-TEST
BASELINE	N	MEAN	SD	N	MEAN	SD	P
Immed Post PTCA	19	.083	.137	41	.101	.111	.0001
6 hrs Post PTCA	15	.091	.137	39	.027	.153	.2676
24 hrs Post PTCA	14	.130	.158	27	.019	.081	.2240

A side branch occlusion ("SBO") occurs when, as a result of balloon inflation, a side artery becomes obstructed, causing loss of blood flow and ischemia distal to the occlusion. Patients with side branch occlusion (SBO) were predicted to have more ischemia than those without. Patients were assigned to the SBO subset if their cardiologist indicated they had significant SBO.

Study results showed significantly higher ischemia test values immediately after and 6 hours after PTCA in patients with SBO. The following data includes patients in all study subsets. The number of patients varies because investigators were not always able to obtain blood samples at all four draw times.

% CHANGE FROM	WITH SBO			WITHOUT SBO			T-TEST
BASELINE	N	MEAN	SD	N	MEAN	SD	P
Immed Post PTCA	8	.228	.144	51	.076	.102	.0005
6 hrs Post PTCA	8	.150	.156	45	.033	.149	.0480
24 hrs Post PTCA	8	.168	.222	33	.013	.098	.1500

EXAMPLE 10
Assessment of the Patency of *In-situ* Coronary Stent

Coronary stents may be inserted during angioplasty and left in place on a permanent basis in order to hold open the artery and thus improve blood flow to the heart muscle and relieve angina symptoms. Stent insertion consists of the insertion of a wire mesh tube (a stent) to prop open an artery that has recently been cleared using angioplasty. The stent is collapsed to a small diameter, placed over an angioplasty balloon catheter and moved into the area of the blockage. When the balloon is

inflated, the stent expands, locks in place and forms a rigid support to hold the artery
open.

Stent use has increased significantly in just the past year, and is now used in
the vast majority of patients, sometimes as an alternative to coronary artery bypass

5   surgery. A stent may be used as an alternative or in combination with angioplasty.
Certain features of the artery blockage make it suitable for using a stent, such as the
size of the artery and location of the blockage. It is usually reserved for lesions that do
not respond to angioplasty alone due to the reclosure of the expanded artery.

In certain selected patients, stents have been shown to reduce the renarrowing

10   that occurs in 30–40 percent of patients following balloon angioplasty or other
procedures using catheters. Stents are also useful to restore normal blood flow and
keep an artery open if it has been torn or injured by the balloon catheter.

However, reclosure (referred to as restenosis) is a common problem with the
stent procedure. In recent years doctors have used stents covered with drugs that

15   interfere with changes in the blood vessel that encourage reclosure. These new stents
have shown some promise for improving the long-term success of this procedure.
Additionally, after a stent procedure has been done, patients are often placed on one or
more blood thinning agents such as aspirin, Ticlopidine and/or Coumadin in order to
prevent or prolong reclosure. Whereas aspirin may be used indefinitely; the other two

20   drugs are used only for four to six weeks.

The present invention provides a mechanism for monitoring the functioning
and patency of an *in situ* stent.

Stent patency was tested in the same study and same patient group in which
post-myocardial infarction patients were studied (see Example 9). The study results

25   showed significantly lower ischemia test values immediately after and 6 hours after
PTCA for those patients with stents. The following data includes patients in the
NonAMI subset only. The number of patients varies because investigators were not
always able to obtain blood samples at all four draw times.

% CHANGE FROM	WITH STENT			WITHOUT STENT			T-TEST
BASELINE	N	MEAN	SD	N	MEAN	SD	P
Immed Post PTCA	37	.089	.105	4	.210	.117	.0373
6 hrs Post PTCA	36	.009	.139	3	.243	.153	.0087
24 hrs Post PTCA	26	.022	.080	1	.071	NA	NA

EXAMPLE 11
Diagnosis and Assessment of Arrhythmic /Dysrhythmic Patients

The present invention provides a rapid method for assessing arrhythmias and diagnosing and measuring dysrhythmias.

Rapid assessment and treatment of arrhythmias is key to a successful outcome: if treated in time, ventricular tachycardia and ventricular fibrillation can be converted into normal rhythm by administration of an electrical shock; alternatively, rapid heart beating can be controlled with medications which identify and destroy the focus of the rhythm disturbances. If an arrhythmia is not promptly diagnosed and treated, a stroke may be the likely result. Arrhythmia prevents the heart from fully pumping blood out of the heart chambers; the undisgorged blood remaining in the heart chamber will pool and clot. If a piece of the blood clot in the atria becomes lodged in an artery in the brain, a stroke results. About 15 percent of strokes occur in people with atrial fibrillation.

Traditionally, electrocardiography, also called ECG or EKG, is used to diagnosis the occurrence of an arrhythmia. (Also utilized are the "12 lead EKG" and signal-averaged electrocardiogram (S.A.E.C.G.), the S.A.E.C.G. to identify people who have the potential to experience a dangerous ventricular arrhythmia and the "12 lead EKG" primarily in people undergoing arrhythmias.) However, all of the electrocardiographic tests yield frequent false positive and false negative results. The present invention provides a method for supplementing all of the aforementioned electrocardiographic tests in order to reduce, if not avoid entirely, the frequency of false positive and false negative diagnoses.

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Other diagnostics techniques typically used are invasive and thus possess greater risk. For instance, transesophageal echocardiography (T.E.E.) is an imaging procedure, in which a tube with a transducer on the end of it is passed down a person's throat and into the esophagus; images from TEE can give very clear pictures of the heart and its structures. Cardiac catheterization is another invasive procedure which allows for measurement and viewing of the pumping ability of the heart muscle, the heart valves and the coronary arteries. The shortcoming of these procedures, however, lies in their invasive nature.

The present invention provides a non-invasive method for diagnosis and measurement of dysrhythmias which can be used in lieu of, or in supplementation of, the aforementioned invasive procedures.

Patients with dysrhythmias undergoing PTCA were predicted to have more ischemia than those without. (Dysrhythmia is cited in the medical literature as a good indicator of ischemia.) In the 63 patient study detailed in Examples 9 and 10, patients were additionally assigned to a dysrhythmia subset if their medical record showed significant dysrhythmia during PTCA. Study results showed significantly higher ischemia test values immediately after and 6 hours after PTCA in patients with significant dysrhythmias. The following data includes patients in all study subsets. The number of patients varies because investigators were not always able to obtain blood samples at all four draw times.

% CHANGE FROM BASELINE	WITH DYSRHYTHMIA			W/O DYSRHYTHMIA			T-TEST
	N	MEAN	SD	N	MEAN	SD	P
Immed Post PTCA	5	.265	.151	57	.079	.103	.0004
6 hrs Post PTCA	5	.204	.175	51	.035	.141	.0150
24 hrs Post PTCA	5	.144	.236	37	.017	.107	.3000

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EXAMPLES 12-23
Use of N-terminus Peptide Probe in the Evaluation of Ischemia

Under the present invention, a four amino acid sequence found within the N-terminus sequence of albumin is the minimum sequence required for cobalt binding. This sequence has been identified as Asp-Ala-His-Lys (abbreviated "DAHK"). The binding characteristics of this tetrapeptide have been extensively studied and it has been determined that this tetrapeptide may be used to detect the presence of ischemia.

Specifically, a biological sample containing albumin is contacted with $CoCl_2 \cdot 6H_2O$. Some of this cobalt will bind to albumin. The remaining free cobalt is then reacted with a known amount of D-A-H-K·R added to the biological sample, wherein R is any chemical group or enzyme, including no group at all or a fluorescent group, capable of being detected. Because D-A-H-K·R has a great affinity to cobalt (association constant about 10^{15}) the free cobalt will attach to it. The D-A-H-K·R differs from Co-D-A-H-K·R spectroscopically. One distinction is that Co-D-A-H-K·R has an extinction coefficient that is 1.5 to 2 times the peptide alone. This phenomenon can be used to determine that the peptide has bound to the cobalt (an increase in absorption at ~ 214 nm using HPLC or other methods).

EXAMPLE 12

To a 0.2 ml sample of blood or plasma was added 50æL 0.1 % $CoCl_2$. The mixture was incubated for 5 to 10 minutes. Thereafter, 50æL of 1 mg/ml of D-A-H-K·R was added to the sample. (R was a polymer or other substance having chemical and physical characteristics that changed when the cobalt binds to the peptide - causing a small current change or any other change that was detected.) The sample was then centrifuged (Centricon 10 or 3) for 5 minutes, followed by HPLC analysis of the filtrate using a ultrahydrogel 120, 5æ column at 60° C; isocratic run, mobile phase acetonitrile: ammonium acetate buffer 30mM pH 8.0, 2:98; at 1 ml/minute and U.V. detection at 214 nm. The peptide peak appeared at ~ 5.88 minutes.

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The same procedure was run with a peptide control (no cobalt). The difference in peak size between test (with cobalt) and control (no cobalt) was proportional to the amount of free cobalt and hence ischemia.

The following preliminary experiments illustrate the properties and critical

5   characteristics of the peptide probe.

EXAMPLE 13

Measurement of Cobalt Binding to HSA and Octapeptide using Cold Cobalt Binding Assay

10

OBJECTIVE: To investigate cobalt binding to the octapeptide and human serum albumin using cold cobalt binding assay.

EXPERIMENTAL: Octapeptide synthesized at the Inorganic Chemistry Department (BAM 1, Pat Ingrey, Cambridge): NH_2-Asp-Ala-His$^+$-Lys$^+$-Ser-Glu-Val-

15 Ala-$CONH_2$

Molecular weight: 855.4 Da.

SOLUTIONS: $CoCl_2$ 0. 1 % (w/v) = 4.2 mM; HSA 3% (w/v)(in 75 mM HEPES pH 7.4) = 0.45 mM; Octapeptide 0.965 mM (in 75 mM HEPES pH 7.4); HEPES 75 mM pH 7.4; DTT 0. 15 % (w/v); NaCl 0.85 % (w/v).

20   METHOD: Fifty æL 0.1 % $CoCl_2$ was added to tubes each containing 200 æL of 75 mM HEPES pH 7.4 or 0.45 mM HSA in HEPES or 0.965 mM Peptide in HEPES; the tubes were allowed to stand at room temperature for 10 minutes; 50 æL DTT 0.15 % was added to one tube (test tube) and distilled H_2O to the other (control tube); the tubes were maintained for 2 minutes at room temperature; 1 ml NaCl 0.85

25 % was then added; the absorbance at A470 nm of the test tube versus the blank was measured.

30

RESULTS:

ID	A470nm		mean A470	% bound
75 mM HEPES pH 7.4	1.087	1.083	1.085	0.0
0.45 mM HSA in HEPES pH 7.4	0.668	0.643	0.656	39.5
0.965 mM Peptide in HEPES pH 7.4	0.638	0.655	0.647	40.4

CONCLUSIONS: Under the conditions used for the binding measurements, this experiment showed that: 1. Cobalt binds to the "octapeptide" (N- Asp-Ala-His[+]-Lys[+]-Ser-Glu-Val-Ala); 2. However the octapeptide (0.965 mM) binds cobalt with a stoichiometry of 1:2.3.

EXAMPLE 14
Mass Spectrometry of Octapeptide after the Addition of Cobalt

OBJECTIVE: To investigate whether mass spectral study would provide molecular weight information for the octapeptide and its corresponding cobalt complex.

SOLUTIONS: Ammonium acetate 20 mM-pH 7.4 (with dilute ammonia solution); $CoCl_2$ 20 æM (in HPLC grade H_2O); Octapeptide 9.5 æM (in HPLC grade H_2O).

METHOD: 20 æM $CoCl_2$ (100 æl) was added to 9.5 æM octapeptide (100 æl) and mass spectrometry carried out.

RESULTS: The main molecular ion peak was observed at 855.4 Da, with minor peaks at 877.4 and 893.4 Da probably as a result of sodium and potassium cluster ions. After the addition of cobalt, an extra molecular ion peak was observed at 912.3 Da.

CONCLUSIONS: Octapeptide showed a molecular ion at 855 Da consistent with the expected molecular weight of the peptide moiety. Octapeptide plus cobalt complex showed a molecular ion at 912 Da suggesting that at least two protons are removed during the complex formation.

EXAMPLE 15
Spectrophotometric Analysis of the Octapeptide and Octapeptide-Cobalt Complex

5   OBJECTIVE: It is clear from the previous mass spectrometry evidence that cobalt forms a complex with the octapeptide with a concomitant loss of two possible protons. Metal complexes in general show distinct absorption in the UV range and in many cases these complexes show either a hypochromic or a bathochromic shift in the spectra. These shifts can be correlated to provide the energy of binding. It was

10   therefore anticipated that the octapeptide-cobalt complexation would provide such information.

         METHOD: The quartz cuvette contained 800 μl octapeptide + 200 μl H_2O(control) or $CoCl_2$ (complex). Spectra were run from 180 to 800 nm on a single beam spectrophotometer.

15   CONCLUSIONS: Cobalt and octapeptide individually have peak absorbances at <200 and 225 nm respectively with little overlap. Following addition of a $CoCl_2$ solution to octapeptide (1.1:1) there was no significant shift in the K_{max} (220 nm). The absorption band at this region broadened indicating complex formation, but the result could not be used to determine the binding energy (constant).

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EXAMPLE 16
Mass Spectrometry of Octapeptide After the Addition of Cobalt

         OBJECTIVE: To investigate whether mass spectral study would provide

25   molecular weight information for the peptide and its corresponding cobalt complex.

         METHOD: 20 or 200 æM $CoCl_2$ (100 æl) was added to 22.9 æM octapeptide (100 æl) to give ratios of cobalt: octapeptide of 1 : 1.1 and 8.7 :1 respectively. Mass spectra for the two samples were carried out as per conditions detailed in the previous experiment.

30   RESULTS: One major molecular ion peak was observed at 855.4 Da representing the octapeptide alone. After the addition of 20 æM cobalt to the octapeptide, two peaks were observed, a major peak at 855.3 representing octapeptide

only plus a minor peak at 912.2 Da representing octapeptide-cobalt complex. Peak ratio of free octapeptide to octapeptide-cobalt complex was 1 :0.15. A similar profile was observed following the addition of 200 æM cobalt to the octapeptide. Peak ratio of free octapeptide to octapeptide-cobalt complex was 1 : 0.9.

5   CONCLUSIONS: On addition of cobalt (59 Da) to the octapeptide, the molecular ion peak should have occurred at 914 Da. The actual peak occurred at 912 Da, representing the loss of two protons. On addition of increasing concentrations of cobalt the peak ratio of free octapeptide to octapeptide-cobalt complex increased.

10   EXAMPLE 17
The Effect of Oxygen on the Binding Capacity of Octapeptide for Cobalt

          OBJECTIVE: Previous experiments have highlighted the requirement of oxygen in promoting cobalt binding to HSA. It may be anticipated that similar effects
15   could be observed in the manner of cobalt binding to the octapeptide.

          METHOD: Octapeptide-cobalt complex (no oxygen): HPLC grade H_2O was bubbled with 100 % helium for 10 minutes prior to use and used to prepare the above solutions. These were further deoxygenated for 10 minutes before adding 200 æM $CoCl_2$ (2 ml) to 22.9 æM octapeptide (2ml). This mixture was again deoxygenated for
20   10 minutes prior to analysis by HPLC.

          Octapeptide-cobalt complex (with oxygen): HPLC grade H_2O was bubbled with 100 % oxygen for 10 minutes prior to use and used to prepare the above solutions. These were further oxygenated for 10 minutes before adding 200 æM $CoCl_2$,(2 ml) to 22. æM octapeptide (2ml). This mixture was again oxygenated for 10
25   minutes prior to analysis by HPLC.

          HPLC Analysis: Chromatography was carried out on a KS437 styrene / DVB polymer column (4.6 mm x 150 mm, pore diameter 100-150 A, BioDynamics) under isocratic conditions of 2 % acetonitrile in 30 mM Ammonium acetate pH 8.0 at a flow rate of 2 ml / min. Peaks were detected at 230 nm. Chromatography gave two
30   distinct peaks at 230 nm, the first peak representing octapeptide-cobalt complex and

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the second peak representing free octapeptide. Octapeptide-Co^{2+} complex formed in
the presence of oxygen gave a higher ratio of complex over free peptide, as indicated
by the first peak being the larger of the two. Octapeptide-Co^{2+} complex formed in the
absence of oxygen again gave two peaks but the second peak was now the larger of

5   the two, indicating less complex formation.

CONCLUSIONS: It would appear that oxygenated conditions enhance cobalt
binding to the octapeptide.

EXAMPLE 18

10   The Effect of pH on the Octapeptide

OBJECTIVE: To optimize chromatography conditions for analysis of
octapeptide by HPLC.

METHOD: The octapeptide was analyzed by HPLC using a KS437 styrene /

15   DVB Polymer column (4.6 mm x 150 mm, pore diameter 100-150 A, 'BioDynamics)
under isocratic conditions of 2 % acetonitrile in 30 mM Ammonium acetate at pH 6.2,
7.5 and 8.0 at a flow rate of 2 ml/min. Peaks were detected at 230 nm.

RESULTS: At pH 6.2, the octapeptide eluted after 1.6 min. At pH 8.0 the
retention time had increased to 2.1 min. When the octapeptide was run at pH 7.5, two

20   peaks were observed at 1.6 and 2.1 min.

CONCLUSIONS: The octapeptide exists in two forms depending on pH. The
protonated form elutes at pH 6.2, and the deprotonated form at pH 8.0.

EXAMPLE 19

25   The Effect of pH on the Binding of Cobalt to the Octapeptide

OBJECTIVE: It was reported that the peptide peak 'shifted' when a solution of
cobalt chloride was added to the octapeptide. It was decided to investigate this
phenomenon fully as this would provide a direct tool for the determination of several
parameters of cobalt binding to the octapeptide.

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METHOD: 200 mM $CoCl_2$ (30 æl) was added to 2.3 mM octapeptide (270 æl), incubated at room temperature for 10 minutes and analyzed by HPLC. <u>HPLC analysis:</u> The octapeptide-cobalt complex was analyzed by HPLC using a KS437 styrene / DVB polymer column (4.6 mm x 150 mm, pore diameter 100-1 50 A, BioDynamics) under isocratic conditions of 2 % acetonitrile in 30 mM Ammonium acetate at pH 6.2 and 8.0 at a flow rate of 2 ml / min. Peaks were detected at 230 nm.

RESULTS: At pH 6.2, a single peak eluted after 1.6 min in the presence and absence of cobalt. At pH 8.0 however a single peak eluted after 1.2 min in the presence of cobalt and at 2.1 min in the absence of cobalt.

CONCLUSIONS: The octapeptide exists in two forms depending on pH. The protonated form that elutes at pH 6.2 is unable to bind cobalt and therefore its elution profile is unchanged. In contrast, the deprotonated form which exists at pH 8.0 is able to bind cobalt, resulting in an increased UV absorption and a decreased retention time, 1.2 min as opposed to 2.1 min for the free octapeptide.

<u>EXAMPLE 20</u>
<u>The Titration of Octapeptide with Increasing Concentrations of Cobalt</u>

OBJECTIVE: To determine whether increasing concentrations of cobalt resulted in a corresponding increase in octapeptide-cobalt complex formation.

METHOD: Octapeptide was used at a final concentration of 2.1 mM throughout, with increasing concentrations of $CoCl_2$, as shown in the Table below:

[$CoCl_2$](mM)	Vol $CoCl_2$ added (æl)	[Octapeptide] (mM)	Vol octapeptide added (æl)	Ratio of octapeptide: $CoCl_2$
0	0	2.3	27	1:0
1	3	2.3	27	21:1

1.25	3	2.3	27	16.8:1
2.25	3	2.3	27	9.3:1
4.5	3	2.3	27	4.7:1
10	3	2.3	27	2.1:1
18	3	2.3	27	1.2:1
36	3	2.3	27	1:1.7
72	3	2.3	27	1:3.4
200	3	2.3	27	1:9.5

HPLC analysis: The octapeptide-cobalt complex was analyzed by HPLC using a KS437 styrene/DVB polymer column (4.6 mm x 150 mm, pore diameter 100-150 A, BioDynamics) under isocratic conditions of 2 % acetonitrile in 30 mM Ammonium acetate at pH 8.0 at a flow rate of 2 ml/min. Peaks were detected at 230 nm.

RESULTS: Mean % Peak Height:

Final [CoCl$_2$] (mM)	Peak 1 (Octapeptide- Co complex)	Peak 2 (unknown)	Peak 3 (Octapeptide)
0	--	3.72	96.28
0.1	7.44	7.08	85.49
0.125	9.79	7.55	82.66
0.225	15.65	15.66	68.52
0.45	25.36	19.67	54.98
1.0	58.66	--	50.42
1.8	61.19	14.97	23.85
3.6	69.55	13.69	16.76
7.2	71.49	14.47	14.05
20.0	82.17	10.27	7.56

From the table immediately preceding, a plot of Log cobalt concentration versus % peak height for peak 3 was produced using Prism software. The 50 % binding constant as deduced from the exponential graph had a value of 0.6461 mM.

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CONCLUSIONS: For 50 % binding, 0.6461 mM Co^{2+} binds to 2.1 mM octapeptide.

Therefore for 100 % binding, 1.2922 mM Co^{2+} binds to 2.1 mM octapeptide. The stoichiometry of cobalt binding to octapeptide is 0.615 cobalt to 1 octapeptide.

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EXAMPLE 21
Liquid Chromatography-Mass Spectrometry of Octapeptide After the Addition of Cobalt

10   OBJECTIVE: To investigate whether mass spectral study would provide molecular weight information for the peptide and its corresponding cobalt complex.

METHOD: 200 mM $CoCl_2$ or H_2O (3 æl) was added to 2.3 mM octapeptide (27 µl) and incubated at room temperature for 10 minutes. LC-MS analysis: Liquid chromatography was performed using a KS437 styrene / DVB polymer column (4.6

15   mm x 150 mm, pore diameter 100-1 50 A, BioDynamics) under isocratic conditions of 2 % acetonitrile in 30 mM Ammonium acetate at pH 8.0 at a flow rate of 0.5 ml/min. Peaks were detected at 230 nm, and analyzed by on line mass spectrometry.

RESULTS: In the control sample, two molecular ion peaks were observed at 855.2 Da, representing the octapeptide alone, and at 877.2 Da, representing an

20   octapeptide-sodium cluster. After the addition of 200 mM cobalt, one major peak was observed at 911.1 Da.

CONCLUSIONS: On addition of cobalt (59 Da) to the octapeptide, the molecular ion peak should occur at 914 Da. The actual peak occurs at 911 Da, representing the loss of protons.

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EXAMPLE 22
Endprotease Lys-C Digest of Octapeptide and Its Subsequent Incubation with Cobalt

OBJECTIVE: Previous experiments confirm that $CoCl_2$ forms a stable

30   complex with the octapeptide. In order to elucidate the site of attachment, the octapeptide was cleaved stereoselectively with the endoprotease Lys-C. The resultant

tetrapeptides upon incubation with $CoCl_2$ would allow elucidation of the probable binding site.

METHOD: Octapeptide 1.97 mg / ml (250 æl) was incubated with the endoprotease Lys-C 100 μg/ml (50 æl) at a substrate : enzyme ratio of 100 : 1 (w/w) in 8.3 mM Tricine, 1.6 mM EDTA pH 8.0 at 37° C for 24 h. After digestion, 27 æl of the product was incubated with 200 mM $CoCl_2$ (3 æl) at 20° C for 10 minutes prior to analysis by HPLC. HPLC Analysis: The products from the Lys-C digest were analyzed by HPLC using an amino column (4.6 mm x 250 mm, pore diameter 100 Å, BioDynamics-73) under isocratic conditions of 30 mM Ammonium acetate at pH 8.0 at a flow rate of 1.5 ml / min. Peaks were detected at 230 nm.

RESULTS: When the digested Lys-C products were run on HPLC, two peaks were observed at 2.6 and 8.9 min, designated tetrapeptides 1 and 2 respectively. Similarly after addition of cobalt to the digested products two peaks were again observed. However, tetrapeptide 1 exhibited an increased UV absorption and decreased retention time, eluting at 1.7 min as opposed to 2.6 min.

CONCLUSIONS: The octapeptide was digested at the C terminus of the lysine residue by the endoprotease yielding two tetrapeptides. On addition of cobalt to the endoprotease digested octapeptide, a single tetrapeptide-cobalt complex was formed with tetrapeptide 1. There appeared to be no effect on tetrapeptide 2.

EXAMPLE 23
Mass Spectrometry Analysis of the Tetrapeptide 1-Cobalt Complex

OBJECTIVE: To determine the identity of tetrapeptide 1.

EXPERIMENTAL: Tetrapeptides 1 and 2 were fractionated by HPLC and collected. $CoCl_2$ 1.2 mM (3 æl) was added to tetrapeptide 1 (27 æl) and incubated at room temperature for 10 minutes. Samples were subsequently run on MS as described previously.

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RESULTS: Tetrapeptide 1 gave two molecular ion peaks at 470.1 and 477.1 Da. Tetrapeptide 2 gave a single peak at 404.0 Da. Tetrapeptide 1 -cobalt complex gave two peaks at 477.1 and 526 Da.

CONCLUSIONS: Tetrapeptide 1 is determined to be Asp-Ala-His-Lys with a molecular weight of 469 Da. Tetrapeptide 2 is determined to be Ser-Glu-Val-Ala (404 Da). Cobalt binds to Asp-Ala-His-Lys forming a complex of 526 Da with a loss of 3 protons. The molecular ion peak observed at 477.1 Da is a contaminant from the Lys-C preparation.

EXAMPLE 24

Manufacture of Calibrator Solutions

Human albumin solutions of 35 mg/ml containing cobalt of molar ratios of 0, 0.4, 0.625, 0.83, 1.25 and 2.5 to 1, cobalt:albumin, were made according to the following protocol.

An albumin solution of 35 mg/ml, Solution A, was made by initially dissolving 40 g solid human albumin (Fraction V, Sigma Chemical Co., St. Louis) in 900 ml 50 mM Tris-Cl, pH7.2, 0.15 NaCl, and assessing albumin concentration with bromo cresol green (BCG) assay (Sigma Chemical Co.). Additional buffer was added to produce an albumin concentration of 35 mg/ml. This solution was allowed to sit at 4°C for at least 24 hours prior to use.

To 500 ml of Solution A, 1.27 ml 0.32M $Co(OAc)_2 \cdot 6H_2O$ (160 mg Co salt/2 ml H_2O) (Sigma Chemical Co.) was added drop-wise with gentle swirling to produce a cobalt:albumin molar ratio of 1.25:1; Solution B. This solution was allowed to sit at room temperature for one hour prior to storage at 4°C until use.

Different volumes of Solutions A and B were mixed to produce additional calibrator solutions:

Cobalt:Albumin ratio	Solution A, ml	Solution B, ml
0	200	0
0.4	133	67
0.625	100	100
0.83	67	133
1.25	0	200

To make a cobalt:albumin calibrator solution of 2.5:1, 0.94 ml of 0.32M Co(OAc)$_2$ was added to 229 ml of Solution A. This solution was permitted to sit at room temperature for one hour and then stored at 4°C until use.

EXAMPLE 25
Quality Control Characterization of Calibrator Solutions

To obtain a cobalt:albumin ratio, one ml aliquots of each of the five calibrator solutions (each of which had been in storage for 24 hours prior to testing) was placed individually in dialysis bags and dialyzed against 400 ml 50mM Tris-Cl, pH7.2, 0.15M NaCl, with three changes of buffer at room temperature. Three to 5 μl of the dialyzates were withdrawn and analyzed for albumin using 1 ml of the BCG dye from Sigma Chemical Co. Absorbance was read at 628 nm after 30 seconds.

Cobalt was assessed by atomic absorption by Galbraith Laboratories, Inc., Knoxville, Tn.

The cobalt:albumin ratios were found to conform to expected values for all five calibrator solutions.

Added Cobalt, Co:albumin	At equilibrium, Co:albumin
0.4	0.16
0.625	0.26

0.83	0.31
1.25	0.46
2.50	0.74

These results indicate that the amount of cobalt bound per albumin molecule following dialysis remained proportional to the original metal concentration in the calibrator solution, indicating that the metal-cobalt complex is stable.

EXAMPLE 26
Generating a Standard Curve using Calibrator Solutions

Aliquots of 200 µl were withdrawn from each calibrator solution stored at 4 °C into 12x75 mm borosilicate tubes and allowed to equilibrate to room temperature for at least 15 minutes.

A standard solution of 0.8% $CoCl_2 \cdot 6H_2O$ in H_2O had been made by dissolving 0.4 g solid in 500 ml deionized H_2O in a 500 ml polystyrene bottle; cobalt concentration was confirmed by atomic absorption by Galbraith Laboratories, Inc. Fifty µl of 0.8% $CoCl_2$ solution was added to each calibrator solution and gently mixed.

A 10mM DTT standard solution had been made by equilibrating the bottle of DTT (DL-dithiothreitol, Sigma Chemical Co.) to room temperature, weighing 12 mg and dissolving same in 8 ml deionized water. The sulfhydryl content of this solution was assessed using Ellman's Reagent, 5,5'-thio-bis(2-nitrobenzoic acid), Sigma Chemical Co. Exactly 10 minutes after addition of $CoCl_2$ solution to the calibrator solutions, 50 µl of the 10 mM DTT solution was added, mixed and allowed to react for 2 minutes. Substitution of DTT with 50 µl 0.9% NaCl was used as the blank. The reaction was quenched by the addition of 1.0 ml 0.9% NaCl. Absorbance at 470 nm on day 1 was read as soon as practicable. Absorbance was read again on days 12, 20 and 23:

Calibrator Co:albumin	A470 Day 1	A470 Day 12	A470 Day 20	A470 Day 23
0	0.26	0.26	0.23	0.27
0.4	0.32	0.30	0.28	0.29
0.625	0.33	0.33	0.31	0.31
1.25	0.39	0.40	0.37	0.37
2.5	0.64	0.60	0.60	0.57

Absorbance was plotted against metal concentration originally present in the
calibrator solution. The plot was found to be substantially linear over the period
studied.

EXAMPLE 27
The NMR Spectra for the Complex of Ni and Albumin N-terminal Amino Acids

Addition of cobalt or nickel chloride to the synthetic albumin N-terminus
octapeptide afforded changes in the appearance of the ^{1}H-NMR spectrum for the
resonances of the first three amino acid residues, with diagnostic changes of the Ala-2
methyl doublet at 1.35 ppm. Titration with $NiCl_2$ gave a sharp diamagnetic ^{1}H-NMR
spectrum, while addition of $CoCl_2$ induced paramagnetism at the binding site resulting
in significant broadening to the resonances associated with the three residues bound
around the metal sphere. Figure 4 shows selected regions of the ^{1}H-NMR spectra
(500 MHz, 10% D_2O in H_2O, 300K) showing the Ala resonances (Ala-2 and Ala-8) of
the octapeptide (A) free of any metal, with a Lys-4 methylene resonance appearing
between the doublets for Ala2 at about 1.35 ppm and for Ala8 at about 1.4, (B) with
0.5 equiv. of $NiCl_2$ added resulting in a shift of the Ni-bound Ala2 doublet to about
1.3, (C) with 1.0 equiv. of $NiCl_2$ added, (D) with 0.5 equiv. of $CoCl_2$ added, and (e)
with 1.0 equiv. of $CoCl_2$ added. In all cases, the appearance and chemical shift of the
resonances attributed to Ser-5, Glu-6, Val-7 and Ala-8 did not change significantly

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after metal addition (up to one equivalent). All these observations were conserved in
metal titration experiments with the synthetic tetrapeptide (N-Asp-Ala-His-Lys).

EXAMPLE 28

5   U.V. Spectroscopic Evidence of Co Binding to Albumin Pep-12 Peptides

The albumin N-terminal peptide Asp-Ala-His-Lys-Ser-Glu-Val-Ala-His-Arg-
Phe-Lys- (Pep 12), was synthesized by Quality Controlled Biochemicals, Inc. both in
N-acetylated-Asp and free Asp forms, each with free C-terminus. Solutions of 1
mg/ml of the two peptides were made in Tris 50 mM 0.9% NaCl pH7.2 and analyzed
10   by UV spectroscopy (Ocean Optics SD 2000 and AIS Model DT 1000 as light
source). U.V. spectra of Pep-12 and acetylated Pep-12 are set forth in Figs. 5A and
5B, respectively. Addition of $CoCl_2 \cdot 6H_2O$ 0.8% (20 μL of the peptide solution)
shows a dramatic shift of the λ maximum of the peptide peak as well as a major
increase in the extinction coefficient for the nonacetylated Pep-12 (Fig. 6A) and no
15   change in the spectrum of the acetylated Pep-12 (Fig. 6B).

Solutions of Pep-12 and acetylated Pep-12 were made into solutions of 1
mg/ml in Tris 50 mM NaCl 0.9% pH7.2. Five mixtures of the two starting peptides
were made: 100% Pep-12, 75:25 Pep-12:AcPep-12, 50:50 Pep-12:AcPep-12, 25:75
Pep-12:AcPep-12 and 100% AcPep-12.

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	1	2	3	4	5
Pep-12 1 mg/ml	20 ml	15	10	5	0
AcPep-12 1 mg/ml	-	5	10	15	20
+/- CoCl2 0.08%	20	20	20	20	20

Spectral analysis of solutions 1-5 is represented in Fig. 7, from which it can be
30   seen that Pep-12 binds cobalt, AcPep-12 does not bind cobalt. Further, as acetylation
increases, cobalt binding goes down.

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EXAMPLE 29

U.V. Spectroscopic Evidence of Co Binding to Albumin Pep-10

Pep-10 was made into 1 mg/ml solutions and incubated with $CoCl_2$ (0.08%). Spectral scans were obtained (data not shown). There was no apparent difference in the absorbance after addition of cobalt, indicating that Pep-10 does not bind cobalt.

EXAMPLE 30

Copper/Cobalt Competition Binding for Albumin Pep-12

Pep-12 (20 µL of 1 mg/ml or 0.014 µMol) was mixed with 5 µL $CuCl_2$ (0.08% or 0.023 µMol) and 20 µL $CoCl_2$ 0.08% (0.067 µMol). The U.V. spectral curve is shown in Fig. 8A. AcPep-12 (20 µL of 1 mg/ml or 0.014 µMol) was also mixed with 5 µL $CuCl_2$ (0.08% or 0.023 µMol) and 20 µL $CoCl_2$ 0.08% (0.067 µMol). The U.V. spectral curve is shown in Fig. 8B. The $CuCl_2$ was added to Pep-12 and AcPep-12 before addition of $CoCl_2$. No shift or change occurred by this manipulation.

Pep-12 binds copper and cannot therefore display a shift and increase absorbance when cobalt is added. The tails appearing on the peaks in Figs. 8A and 8B are due to absorbance of copper in the U.V. range.

EXAMPLE 31

Enzymatic Acetylation of N-Terminal Pep-8 and Human Serum Albumin

Human serum albumin (Sigma A-1653) was incubated at 37°C for 1 h with N-acetyl transferase and acetyl CoA, and spectral scans were obtained at various times (2-60 minutes). A steady increase at A235 was observed (assuming A235 reflects acetylation), reaching a plateau at about 40 minutes (data not shown).

Likewise, Pep-8 (Asp-Ala-His-Lys-Ser-Glu-Val-Ala), was acetylated according to the following conditions:

	1	2	3	4	5	6	7	8
Pep-8	250 µL	250 µL	250 µL	250 µL				
NAT	50 µL			50 µL		50 µL		

AcCoA	25 μL	25 μL			25 μL			25 μL
Buffer		50 μL	75 μL	25 μL	300 μL	275 μL	325 μL	250 μL
CoCl$_2$	+/- 50 μL	+/- 50 μL	+/- 50 μL	+/- 50 μL	+/- 50 μL	+/- 50 μL	+/- 50 μL	+/- 50 μL

The Pep-8 was 1 mg/ml in a solution of Tris 50 mM, pH 7.5, 0.15 NaCl. The N-acetyl-transferase was 10 U/mL (Sigma A426). The acetyl CoA was 10 mg/ml in H$_2$O (Sigma A2056). The Buffer was Tris 50 mM, pH 7.5, 0.15 NaCl. After completion of the reaction, test tubes were centrifuged using Centricon (3000 MW cutoff) to remove N-acetyl transferase and acetyl CoA which introduce interference in the U.V. range. The +/- in the final row refers to the fact that the absorbance at 235 was measured with and without addition of CoCl$_2$. Addition of cobalt did not result in a shift of the peak, indicating that the acetylated Pep-8 did not bind cobalt.

Fig. 9 is the subtracted scan of the centrifuged acetylated Pep-8, plus reaction mixture and cobalt, minus the reaction mixture without the cobalt, showing a peak at about 280 nm, presumably the acetylated Pep-8.

EXAMPLE 32

Confirmation of Ni, Co and Co Binding to Modified Peptides by ¹H-NMR (800 MHz)
Peptide I: The N-terminal dodecapeptide, Asp-Ala-His-Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys.

The N-terminal dodecapeptide was titrated with each of cobalt, copper and nickel. The methyl signals of the two Ala residues (positions 2 and 8) appear at the same resonance, namely 1.3 ppm. Fig. 10A is Peptide 1 at pH 2.55 with no metal. Fig. 10B is Peptide 1 at pH 7.33 with no metal. Titration with 0.3 equivalent NiCl$_2$ at 7.30 is characterized by the appearance of a set of peaks at 1.25 ppm which is ·ristic of the methyl of Ala at position 2 (Fig. 10C). After the addition of one ·t of NiCl$_2$ at pH 7.33, the methyl groups of Ala at positions 2 (1.3 ppm) and ·) are equivalent, showing that the metal binds and that the binding is ·c (Fig. 10D). Fig. 10 scans were conducted at 800 MHz, 10% Ala-Me region).

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The addition of $CoCl_2$ also shows binding but the peaks are broader with a shift in the methyl group Ala 2 to 1.7 ppm (Fig. 11). Fig. 11A shows Peptide 1's Ala2 and Ala8 methyl signals at 1.3 (pH 2.56). Fig. 11B shows Peptide 1 at pH 7.45. Fig. 11C shows widening of the 1.3 ppm peak as 0.5 equivalent $CoCl_2$ is added at pH 7.11. Fig. 11D shows a separate peak for Ala2-Me at 1.7 ppm with 1.0 equivalent $CoCl_2$ at pH 7.68. Fig. 11 scans were conducted at 500 MHz, 10% D_2O/90% H_2O (Ala-Me region).

The addition of $CuSO_4$ causes even more broadening of both methyl groups at positions 2 and 8 to the point where, after addition of 1 equivalent of $CuSO_4$, both signals are lost (Fig. 12). Fig. 12A shows Peptide 1 at pH 2.56 with Ala2 and Ala8 methyl signals at 1.35 ppm. Fig. 12B shows Peptide 1 at pH 7.54. Fig. 12C shows Peptide 1 with a broadening of the signal at 1.35 ppm, due to about 0.5 equivalent $CuSO_4$ (pH 7.24). Fig. 12D shows Peptide 1 with about 1 equivalent $CuSO_4$ at pH 7.27. Fig. 12 scans were conducted at 500 MHz, 10% D_2O/90% H_2O (Ala-Me region).

Peptide 2: The N-Terminal dodecapeptide, Asp-Ala-His-Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys, in which the amino group of the N-terminal Asp has been acetylated.

Addition of $NiCl_2$ to the acetylated derivative does not result in binding, i.e., there is no appearance of additional peaks (Fig. 13). However, addition of even one equivalent of $NiCl_2$ broadens the spectrum considerably due to the fact that the nickel is free in solution. Fig. 13A shows Peptide 2 at pH 2.63 with the Ala2 and Ala8 Me signals at about 1.28 ppm. Fig. 13B shows Peptide 2 at pH 7.36. Fig. 13C shows Peptide 2 with about 0.5 equivalent $NiCl_2$ at pH 7.09. Fig. 13D shows Peptide 2 with about 1 equivalent $NiCl_2$ at pH 7.20. Fig. 13 scans were conducted at 800 MHz, 10% D_2O/90% H_2O (Ala-Me region).

Peptide 3: The N-Terminal Unodecapeptide, Ala-His-Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys, in which the terminal Asp is missing.

The N-terminal residue is Ala and consequently the position of the doublet from the methyl group is pH dependent (Fig 14). Addition of $NiCl_2$ does not result in complex formation. Fig. 14A shows Peptide 3 at pH 2.83 with the Ala2 signal at 1.5 and the Ala8 signal at 1.3. Fig. 14B shows Peptide 3 at pH 7.15. Fig. 14C shows

5   Peptide 3 with 0.13 equivalent $NiCl_2$ at pH 7.28. Fig. 14D shows Peptide 3 with about 0.25 equivalent $NiCl_2$ at pH 7.80. Fig. 14E shows Peptide 3 with 0.5 equivalent $NiCl_2$ at pH 8.30. Fig. 14 scans were conducted at 500 MHz, 10% D_2O/90% H_2O (Ala-Me region).

10   **Peptide 4: The N-Terminal decapeptide, His-Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys, in which Asp-Ala has been removed.**

Upon addition of $NiCl_2$ the spectrum broadens unrecognizably with no evidence of binding (Fig. 15). Fig. 15A shows Peptide 4 with an Ala8 signal at 1.8 ppm at pH 2.72. Fig. 15B shows Peptide 4 at pH 7.30. Fig. 15C shows Peptide 4

15   with 0.5 equivalent $NiCl_2$, pH 8.30. Fig. 15D shows Peptide 4 with about 1 equivalent $NiCl_2$ at pH 8.10. Fig. 15 scans were conducted at 800 MHz, 10% D_2O/90% H_2O (Ala-Me region).

Peptide 5: The nonpeptide, Lys-Ser-Glu-Val-Ala-His-Arg-Phe-Lys, in which the

20   **tripeptide Asp-Ala-His is missing.**

Again there is not much change in the spectrum after addition of 0.3 equivalents of $NiCl_2$ (Fig. 16C) except for the decrease in peak intensity and peak broadening upon addition of less than 1 equivalent of metal ions (Fig. 16D). There is no evidence of metal binding. Fig. 16A is Peptide 5 at pH 2.90 with the Ala8 signal at

25   1.3 ppm. Fig. 16B is Peptide 5 at pH 7.19. Fig. 16C is Peptide 5 with 0.3 equivalent $NiCl_2$, pH 7.02. Fig. 16D is Peptide 5 with about 0.6 equivalent $NiCl_2$ at pH 7.02. Fig. 16 scans were conducted at 500 MHz, 10% D_2O/90% H_2O (Ala-Me region).

Peptide 6: The N-terminal tetrapeptide, Asp-Ala-His-Lys.

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The addition of $NiCl_2$ (Fig. 17), $CoCl_2$ (Fig. 18) and $CuSO_4$ (Fig. 19) all gave diagnostic changes consistent with metal ion binding. The spectra resemble those obtained with the dodecapeptide (Peptide 1) and not those obtained with Peptides 2, 3, 4 and 5.

5   Fig. 17A is the N-terminal tetrapeptide at pH 2.49 with an Ala2 signal at 1.3 ppm. Fig. 17B is the tetrapeptide at pH 7.44. Fig. 17C is the tetrapeptide with about 0.8 equivalent $NiCl_2$ at pH 7.42. Fig. 17D is the tetrapeptide with about 1 equivalent $NiCl_2$ at pH 7.80.

Fig. 18A is the tetrapeptide at pH 7.44 with the Ala2 peak at 1.3 ppm. Fig. 10   18B is the tetrapeptide with about 0.3 equivalent $CoCl_2$ at pH 7.23. Fig. 18C is the tetrapeptide with about 0.8 equivalent $CoCl_2$ at pH 7.33.

Fig. 19A is the tetrapeptide at pH 7.31 with the Ala2 signal at 1.3 ppm. Fig. 19B is the tetrapeptide with about 0.5 equivalent $CuSO_4$ at pH 7.26. Fig. 19C is the tetrapeptide with about 1.0 equivalent $CuSO_4$ at pH 7.32.

15   Figs. 17-19 scans were conducted at 800 MHz, 10% H_2O/90% D_2O (Ala-Me region).

* * * * *

The above description of the invention is intended to be illustrative and not 20   limiting. Various changes or modification in the embodiments described may occur to those skilled in the art. These can be made without departing from the spirit or scope of the invention.

What is claimed is:

1.   A method for detecting the occurrence or non-occurrence of an ischemic event in a patient comprising the steps of:

5   (a)   contacting a biological sample containing albumin from said patient with an excess quantity of a metal ion salt, whereby said metal ion binds to the N-terminus of naturally occurring human albumin, to form a mixture containing bound metal ions and unbound metal ions,

           (b)   determining the amount of metal ions bound to the albumin N-
10   terminus, and

           (c)   correlating the amount of bound metal ions to a known value to determine the occurrence or non-occurrence of an ischemic event.

2.   The method of claim 1, wherein said sample is serum or plasma.

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3.   The method of claim 1, wherein the sample is purified albumin.

4.   The method of claim 1, wherein said metal ion salt is a salt of a metal selected from the group consisting of V, As, Co, Cu, Sb, Cr, Mo, Mn, Ba, Zn, Ni, Hg, Cd, Fe,
20   Pb, Au and Ag.

5.   The method of claim 1, wherein said metal ion is cobalt.

6.   The method of claim 1, wherein step (b) is conducted using atomic absorption
25   spectroscopy, atomic emission spectroscopy or an immunological assay.

7.   The method of claim 6, wherein said immunological assay is conducted using an antibody specific to an antigen comprising the compound Asp-Ala-His-Lys-R, wherein R is said metal ion.

8.   The method of claim 6, wherein said immunological assay is conducted using an antibody to a human serum albumin-metal complex.

9.   A method of detecting the occurrence or non-occurrence of an ischemic event in a patient comprising the steps of:

(a)   contacting a biological sample containing albumin from said patient with a predetermined excess quantity of a salt of a metal selected from the group consisting of V, As, Co, Cu, Sb, Cr, Mo, Mn, Ba, Zn, Ni, Hg, Cd, Fe, Pb, Au and Ag, to form a mixture containing metal ions bound to the N-terminus of albumin and unbound metal ions,

(b)   contacting said mixture with an aqueous color forming compound solution to form a colored solution, wherein said compound forms color when bound to said unbound metal ion,

(c)   determining the color intensity of said colored solution to detect the presence of unbound metal ions to provide a measure of bound metal ions, and

(d)   correlating the amount of bound metal ions to a known value to determine the occurrence or non-occurrence of an ischemic event.

10.   The method of claim 9, wherein said aqueous color forming compound comprises the compound Asp-Ala-His-Lys-R, wherein R is any group capable of forming color when bound to said metal ion.

11.   The method of claim 9, wherein said sample is serum or plasma.

12.   The method of claim 9, wherein said sample is purified albumin.

13.   The method of claim 9, wherein said metal ion salt is a salt of cobalt.

14.   A method for ruling-out the existence of ischemia in a patient, wherein said patient possesses one or more cardiac risk factors, comprising

(a) application of the method of claim 1 or 9 to said patient;

(b) subjecting said patient to an exercise treadmill test followed by a second application of the same method of claim 1 or 9;

(b)   comparing the results of the two applications of said method.

15.   A method for evaluation of a patient presenting with angina or angina-like symptoms to detect the occurrence or non-occurrence of a myocardial infarction, comprising

(a)   application of the method of claim 1 or 9,

(b)   application of an electrocardiographic test,

(c)   correlating the results of step (a) with the results of said electrocardiographic test to determine the occurrence or non-occurrence of a myocardial infarction.

16.   A method for supplementing electrocardiographic results to determine the occurrence or non-occurrence of an ischemic event, comprising

(a)   application of the method of claim 1 or 9,

(b)   application of an electrocardiographic test, and

(c)   correlating the results of step (a) with the results of said electrocardiographic test to determine the occurrence or non-occurrence of an ischemic event.

17.   A method for comparing levels of ischemia in patients at rest ~~and~~ during exercise, comprising application of the following steps at designated times:

(a)   application of the method of claim 1 or 9 at a first designated time,

(b)   administration of an exercise treadmill test followed by a second application of the same method employed in step (a),

(c)   comparing the results of step (a) with the results obtained in step (b), and

(d)   repeating steps (a) and (b) at additional designated times,

wherein results obtained designated at each designated time are compared.

18.   The method of claim 17, wherein said designated times are three months, six months and one year.

19.   A method for detecting the occurrence or non-occurrence of an ischemic event in a patient comprising the steps of:

(a)   detecting the amount of endogenous copper ions present in a purified albumin sample from said patient, and

(b)   correlating the quantity of copper ions present with a known value to determine the occurrence or non-occurrence of an ischemic event.

20.   The method of claim 19, wherein said detecting step is conducted using atomic absorption spectroscopy, atomic emission spectroscopy or an immunological assay.

21.   The method of claim 20, wherein said immunological assay is conducted using an antibody specific to an antigen comprising the compound Asp-Ala-His-Lys-R, wherein R is copper.

22.   The method of claim 20, wherein said immunological assay is conducted using an antibody to a human serum albumin-copper complex.

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23.   A method for ruling-out the existence of ischemia in a patient, wherein said patient possesses one or more cardiac risk factors, comprising:

(a)   applying the method of claim 19 to the patient,

(b)   subjecting said patient to an exercise treadmill test followed by a second application of the method of claim 19;

(b)   comparing the results of the two applications of the method of claim 19.

24.   A method for evaluation of a patient presenting with angina or angina-like symptoms to detect the occurrence or non-occurrence of a myocardial infarction, comprising

(a)   application of the method of claim 19,

(b)   application of an electrocardiographic test,

(c)   correlating the results of application of the method of claim 19 with the results of said electrocardiographic test to determine the occurrence or non-occurrence of a myocardial infarction.

25.   A method for supplementing electrocardiographic results to determine the occurrence or non-occurrence of an ischemic event, comprising

(a)   application of the method of claim 19,

(b)   application of an electrocardiographic test, and

(c)   correlating the results of application of the method of claim 19 with the results of said electrocardiographic test to determine the occurrence or non-occurrence of an ischemic event.

26.   A method for comparing levels of ischemia in patients at rest and during exercise, comprising application of the following steps at designated times:

(a)   application of the method of claim 19 at a first designated time,

(b)   administration of an exercise treadmill test followed by a second application of the method of claim 19,

(c)   comparing the results of the application of the method of claim 19 prior to administration of the exercise treadmill test with the results of the application of the method of claim 19 after administration of the exercise treadmill test, and

(d)   repeating steps (a) and (b) at additional designated times, wherein results obtained at said designated times are compared.

27.   The method of claim 26, wherein said designated times are three months, six months and one year.

28.   A method of detecting or measuring an ischemic event in a patient comprising:

(a)   contacting a patient sample comprising naturally-occurring albumin and optionally albumin N-terminal derivatives with an excess quantity of metal ion that binds to the N-terminus of naturally-occurring albumin, whereby albumin-metal complexes are formed,

(b)   partitioning the complexes from said derivatives, if any,

(c)   measuring at least one of said derivatives, if any, and

(d)   comparing said measured derivative to a known value, whereby the ischemic event may be detected or measured.

29.   The method of claim 28 wherein said metal is Ni or Co.

30.   The method of claim 28 wherein said metal of step (a) is bound to a solid support and said partitioning step (b) comprises separating said derivatives from the solid support to which the metal is bound.

31.   The method of claim 28 wherein said metal of step (a) is in solution and said partitioning step (b) comprises contacting said complexes with an antibody to the albumin-metal complex, said antibody being bound to a solid support.

32.   The method of claim 28 wherein said measuring step (c) comprises contacting said derivative with an antibody to the derivative.

33.   A method for detecting or measuring an ischemic event in a patient comprising:

        (a)   contacting a patient sample comprising naturally-occurring albumin and optionally albumin N-terminal derivatives with an excess of a metal ion, whereby a albumin-metal complex is formed,

        (b)   contacting the mixture of step (a) with an antibody to said complex, said antibody being bound to a solid support,

        (c)   separating the complex from said N-terminal derivatives, if any,

        (d)   measuring the amount of at least one N-terminal derivative, if any, and

        (e)   comparing the measured N-terminal derivative to a known value, whereby an ischemic event may be detected or measured.

34.   The method of claim 33, wherein the metal ion is cobalt ion.

35.   The method of claim 33, wherein said measuring step (d) comprises contacting the derivative with an antibody.

36.   An immunoassay diagnostic kit for an ischemic event comprising:

an excess quantity of a metal ion to mix with a patient sample which comprises naturally-occurring albumin and optionally albumin N-terminal derivatives, said naturally-occurring albumin forming a complex with said metal ion,

5   a first elongated solid support having a first and a second end, said first end having a filter for application of said patient sample mixture, an area of immobilized antibody to said albumin-metal complex between the first end the second end, and an area of immobilized ligand to albumin proximate the second end,

whereby after application of said mixture of patient sample and metal ion to

10   said filter, said albumin-metal complex is immobilized at said area of immobilized antibody, and said albumin N-terminal derivatives migrate and bind to the albumin ligand proximate the second end.

37.   The kit of claim 36, wherein said metal ion is cobalt ion.

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38.   The kit of claim 36, further comprising an end of process indicator at the second end of said solid support.

39.   The kit of claim 36, further comprising a second elongated solid support

20   having a first and second end, said second support first end sharing said filter for application of said patient sample mixture with said first elongated support, and having an area of immobilized ligand to albumin between the first and second ends, said second support serving as a control.

25   40.   The kit of claim 39, further comprising an end of process indicator at the second end of said second solid support.

41.   An immunoassay diagnostic kit for an ischemic event comprising:

a circular solid support comprising an interior filter circle surrounded by an inner concentric ring and an outer concentric ring, wherein

said inner filter circle is for application of a patient sample comprising naturally-occurring albumin and optionally albumin N-terminal derivatives, said sample having been mixed with an excess quantity of a metal ion, whereby an albumin-metal complex has been formed,

said inner concentric ring is divided into a first and second half, said first half containing a ligand to said albumin-metal complex, and

said outer concentric ring is divided into a first and second half, each said outer ring halves aligned with the inner ring halves, and each said outer ring halves containing ligands to a non N-terminus epitope of naturally-occurring albumin and to albumin N-terminal derivatives.

42.   An immunoassay diagnostic kit for an ischemic event comprising:

a circular solid support comprising an inner filter circle surrounded by a concentric ring, wherein

said inner filter circle is for application of a patient sample comprising naturally-occurring albumin and optionally albumin N-terminal derivatives, said sample having been mixed with an excess quantity of a metal ion, whereby an albumin-metal complex has been formed, and

said concentric ring is divided into a first and a second half, said first half having a ligand to the albumin-metal complex, and the second half having ligands to a non N-terminus epitope of naturally-occurring albumin and to albumin N-terminal derivatives.

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43.   A method of detecting or measuring an ischemic event in a patient comprising:

(a)   contacting a patient sample comprising naturally-occurring albumin and optionally albumin N-terminal derivatives with an excess quantity of a metal ion bound to a solid support, whereby the metal ion binds to the N-terminus of naturally-occurring albumin, forming albumin-metal complexes,

(b)   separating the complexes from said derivatives, if any,

(c)   measuring at least one of said derivatives, if any, and

(d)   comparing said measured derivative to known value, whereby the ischemic event may be detected or measured.

44.   The method of claim 43 wherein the metal ion is nickel ion.

45.   The method of claim 43 wherein the solid support is a diacetate or a phosphonate matrix.

46.   The method of claim 43 wherein said measuring step (c) comprises contacting said derivative with an antibody to the derivative.

47.   A metal affinity diagnostic kit for an ischemic event comprising:

a first elongated solid support having a first and a second end, said first end having a filter for application of a patient sample, an area of immobilized metal ion between the first and the second end, and an area of immobilized ligand to naturally-occurring albumin or albumin N-terminal derivatives proximate the second end.

48.   The kit of claim 47, wherein said immobilized metal is nickel.

49.   The kit of claim 47, further comprising an end of process indicator at the second end of said first solid support.

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50.   The kit of claim 47, further comprising a second elongated solid support having a first and second end, said second support first end sharing said filter for application of said patient sample with said first solid support, and having an area of immobilized ligand to naturally-occurring albumin and albumin N-terminal derivatives proximate the second end, said second support serving as a control.

5

51.   The kit of claim 50, further comprising and end of process indicator at the second end of said second solid support.

10   52.   A monoclonal antibody directed to an epitope at the N-terminus of the albumin N-terminal derivative which lacks the four N-terminal amino acids of SEQ. ID. NO. 1.

53.   A monoclonal antibody directed to an epitope at the N-terminus of the albumin N-terminal derivative which lacks the three N-terminal amino acids of SEQ. ID. NO.

15   1.

54.   A monoclonal antibody directed to an epitope at the N-terminus of the albumin N-terminal derivative which lacks the two N-terminal amino acids of SEQ. ID. NO.

1.

20

55.   A monoclonal antibody directed to an epitope at the N-terminus of the albumin N-terminal derivative which lacks the N-terminal amino acid of SEQ. ID NO. 1.

56.   A monoclonal antibody directed to an epitope at the N-terminus of SEQ. ID

25   NO. 2.

57.   A calibrator composition comprising a predetermined molar ratio of naturally-
occurring albumin and a metal that complexes to the N-terminus of said albumin,
whereby complexed albumin and unbound albumin form when said composition is in
aqueous solution, wherein said ratio is between 0.1:1 and 1:0.1.

58.   The composition of claim 57 wherein said metal is selected from the group
consisting of Cu, Ni and Co.

59.   The composition of claim 57 wherein the predetermined ratio of albumin to
metal is 3:1.

60.   The composition of claim 57 wherein the predetermined ratio of albumin to
metal is 1:3.

61.   The composition of claim 57 wherein the predetermined ratio of albumin to
metal is 1:1.

62.   A method of calibrating an analyzer that detects or measures an ischemic event
according to the method of claim 1, comprising the step of:
        applying the calibrator solution of claim 57 to the analyzer to determine the
amount of metal ions bound to the albumin N-terminus, whereby the predetermined
ratio of albumin to metal serves as a standard for calibration.

63.   A method of calibrating an analyzer that detects or measures an ischemic event according to the method of claim 15, comprising the steps of:

        (a)   mixing the calibrator composition solution of claim 57 with a predetermined amount of an excess metal salt, whereby said unbound albumin binds to said excess metal ion, generating unbound metal ions,

        (b)   contacting the mixture of step (a) with color forming solution to form a colored solution,

        (c)   applying the mixture of step (b) to the analyzer, whereby the predetermined ratio of albumin to metal serves as a standard for calibration.

64.   A method of calibrating an analyzer that detects or measures an ischemic event according to the method of claim 19, comprising the step of:

        applying the calibrator solution of claim 57 wherein the metal is copper to the analyzer to determine the amount of copper ions bound to the albumin N-terminus, whereby the predetermined ratio of albumin to copper serves as a standard for calibration.

AMENDED CLAIMS
[received by the International Bureau on 29 February 2000 (29.02.00);
original claims 52-56 and 63 amended; new claims 65-76 added;
remaining claims unchanged (4 pages)]

50.   The kit of claim 47, further comprising a second elongated solid support having a first and second end, said second support first end sharing said filter for application of said patient sample with said first solid support, and having an area of immobilized ligand to naturally-occurring albumin and albumin N-terminal derivatives proximate the second end, said second support serving as a control.

51.   The kit of claim 50, further comprising and end of process indicator at the second end of said second solid support.

52.   A ligand directed to an epitope at the N-terminus of the albumin N-terminal derivative which lacks the four N-terminal amino acids of SEQ. ID. NO. 1.

53.   A ligand directed to an epitope at the N-terminus of the albumin N-terminal derivative which lacks the three N-terminal amino acids of SEQ. ID. NO. 1.

54.   A ligand directed to an epitope at the N-terminus of the albumin N-terminal derivative which lacks the two N-terminal amino acids of SEQ. ID. NO. 1.

55.   A ligand directed to an epitope at the N-terminus of the albumin N-terminal derivative which lacks the N-terminal amino acid of SEQ. ID NO. 1.

56.   A ligand to an epitope at the N-terminus of SEQ. ID NO. 2.

63.   A method of calibrating an analyzer that detects or measures an ischemic event according to the method of claim 9, comprising the steps of:

        (a)   mixing the calibrator composition solution of claim 57 with a predetermined amount of an excess metal salt, whereby said unbound albumin binds to said excess metal ion, generating unbound metal ions,

        (b)   contacting the mixture of step (a) with color forming compound to form a colored solution, and

        (c)   applying the mixture of step (b) to the analyzer, whereby the predetermined ratio of albumin to metal serves as a standard for calibration.

64.   A method of calibrating an analyzer that detects or measures an ischemic event according to the method of claim 19, comprising the step of:

        applying the calibrator solution of claim 57 wherein the metal is copper to the analyzer to determine the amount of copper ions bound to the albumin N-terminus, whereby the predetermined ratio of albumin to copper serves as a standard for calibration.

65.   A method of detecting an albumin N-terminal derivative which lacks four N-terminal amino acids of SEQ. ID. NO. 1, comprising contacting a sample comprising said derivative with the ligand of claim 52.

66.   A method of detecting an albumin N-terminal derivative which lacks three N-terminal amino acids of SEQ. ID. NO. 1, comprising contacting a sample comprising said derivative with the ligand of claim 53.

67.   A method of detecting an albumin N-terminal derivative which lacks two N-terminal amino acids of SEQ. ID. NO. 1, comprising contacting a sample comprising said derivative with the ligand of claim 54.

68.   A method of detecting an albumin N-terminal derivative which lacks an N-terminal amino acid of SEQ. ID NO. 1, comprising contacting a sample comprising said derivative with the ligand of claim 55.

69.   A method of detecting an albumin N-terminal derivative which is acetylated at its N-terminal Asp residue (SEQ. ID. NO. 2), comprising contacting a sample comprising said derivative with the ligand of claim 56.

70.   A diagnostic kit for an ischemic event comprising:

        a circular solid support comprising an interior filter circle surrounded by an inner concentric ring and an outer concentric ring, wherein

        said inner filter circle is for application of a patient sample comprising naturally-occurring albumin and optionally albumin N-terminal derivatives,

        said inner concentric ring is divided into a first and second half, said first half containing an excess amount of bound metal ion to bind to the N-terminus of said naturally-occurring albumin, and

        said outer concentric ring is divided into a first and second half, each said outer ring halves aligned with the inner ring halves, and each said outer ring halves containing ligands to a non-N-terminus epitope of naturally occurring albumin and to albumin N-terminal derivatives.

71.   A diagnostic kit for an ischemic event comprising:

        a circular solid support comprising an inner filter circle surrounded by a concentric ring, wherein

        said inner filter circle is for application of a patient sample comprising naturally-occurring albumin and optionally albumin N-terminal derivatives,

        said concentric ring is divided into a first and second half, said first half having an excess amount of bound metal to bind to the N-terminus of naturally-occurring albumin, and the second half having ligands to a non-N-terminus epitope of naturally-occurring albumin and to albumin N-terminal derivatives.

72.   A calibrator composition comprising a predetermined molar ratio of naturally-occurring albumin and albumin N-terminal derivatives, wherein said ratio is between 0.1:1 and 1:0.1.

AMENDED SHEET (ARTICLE 19)

73.   The calibrator composition of claim 72 wherein the molar ratio of naturally-occurring albumin to albumin N-terminal derivatives is 3:1.

74.   The calibrator composition of claim 72 wherein the molar ratio of naturally-occurring albumin to albumin N-terminal derivatives is 1:3.

75.   The calibrator composition of claim 72 wherein the molar ratio of naturally-occurring albumin to albumin N-terminal derivatives is 1:1.

76.   A method of calibrating an analyzer that detects or measures an ischemic event according to the method of claim 9 comprising the steps of:

       (a)   mixing the calibrator composition of claim 72 with a predetermined amount of an excess metal salt, whereby naturally-occurring albumin binds to said excess metal ion, generating unbound metal ions,

       (b)   contacting the mixture of step (a) with a color forming compound to form a colored solution,

       (c)   applying the mixture of step (b) to the analyzer, whereby the predetermined ratio of naturally-occurring albumin to albumin N-terminal derivatives serves as a standard for calibration.
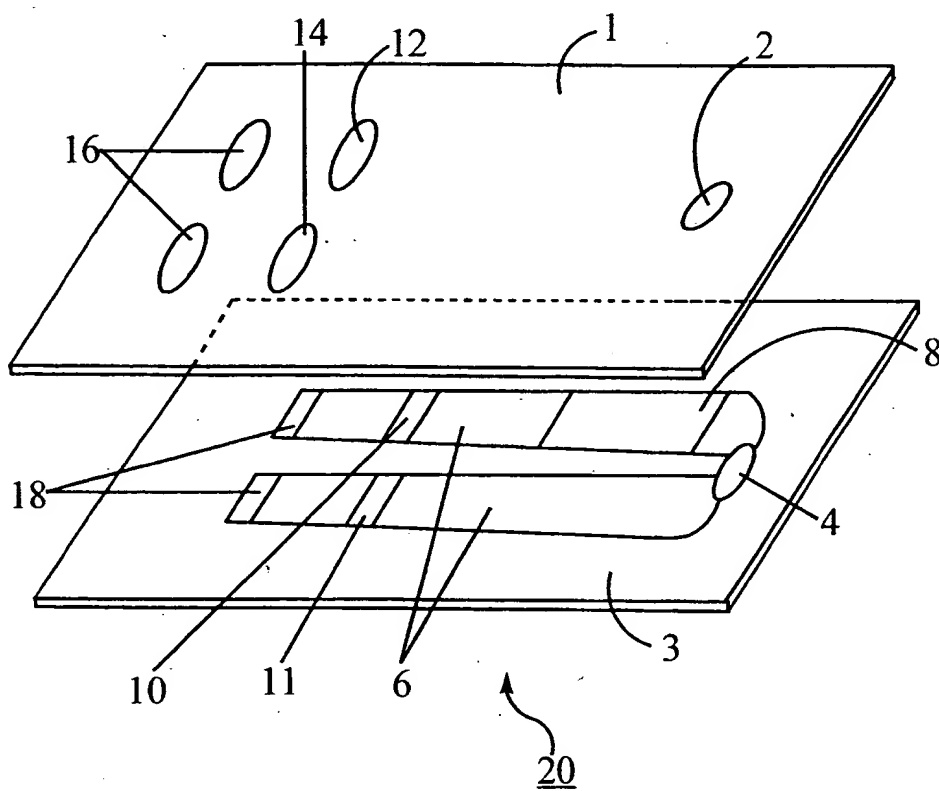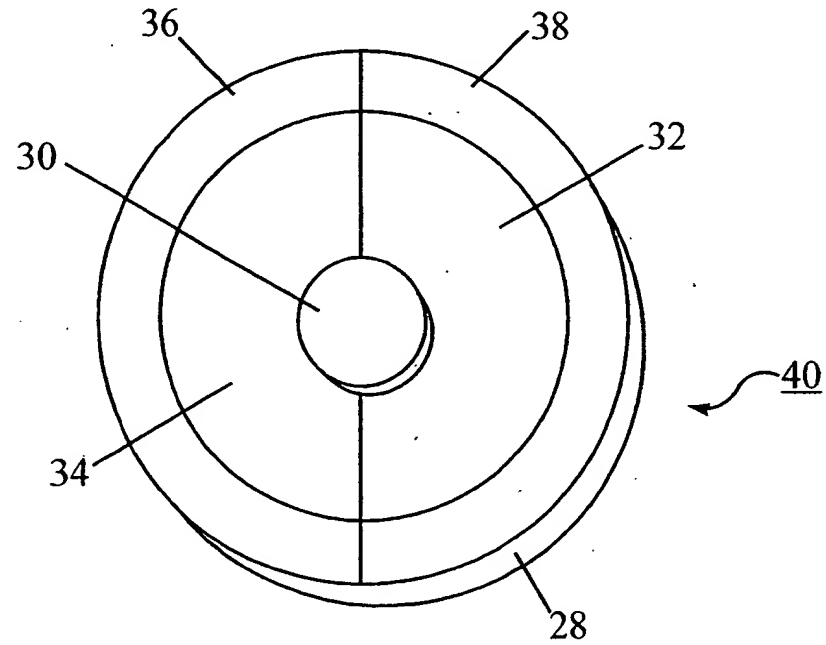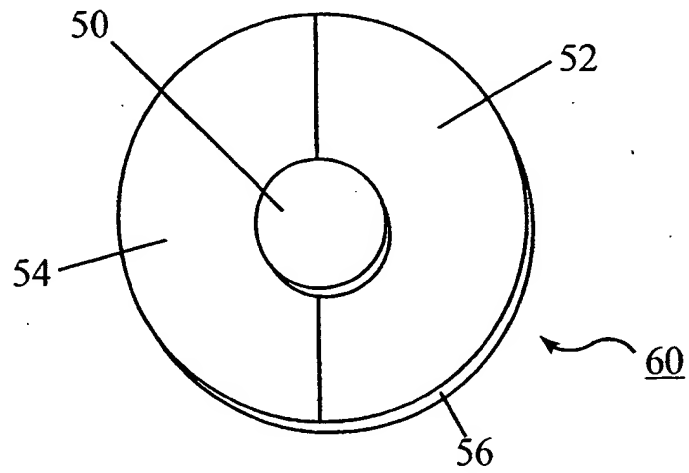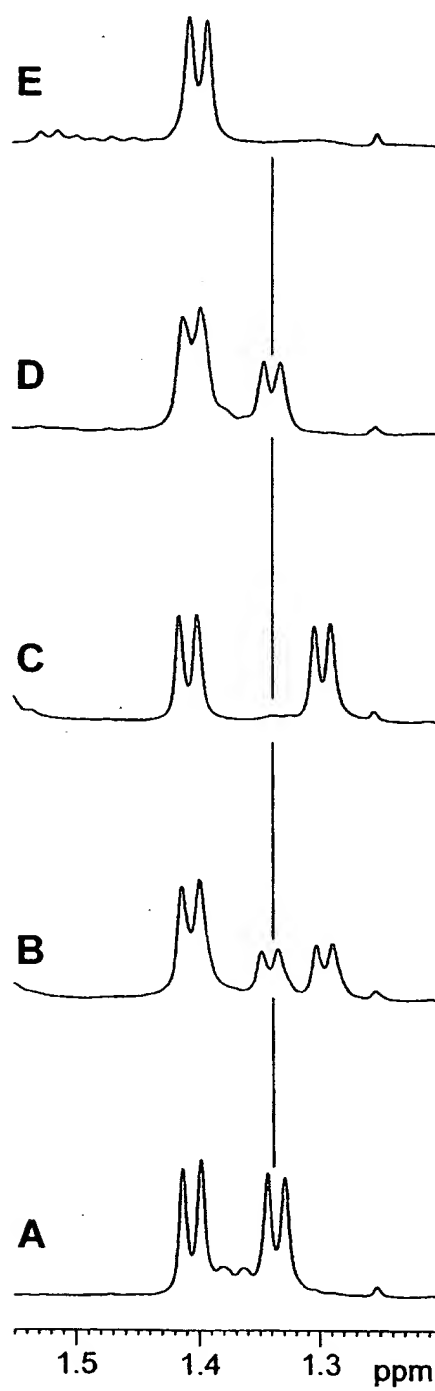
Fig. 1

Fig. 2

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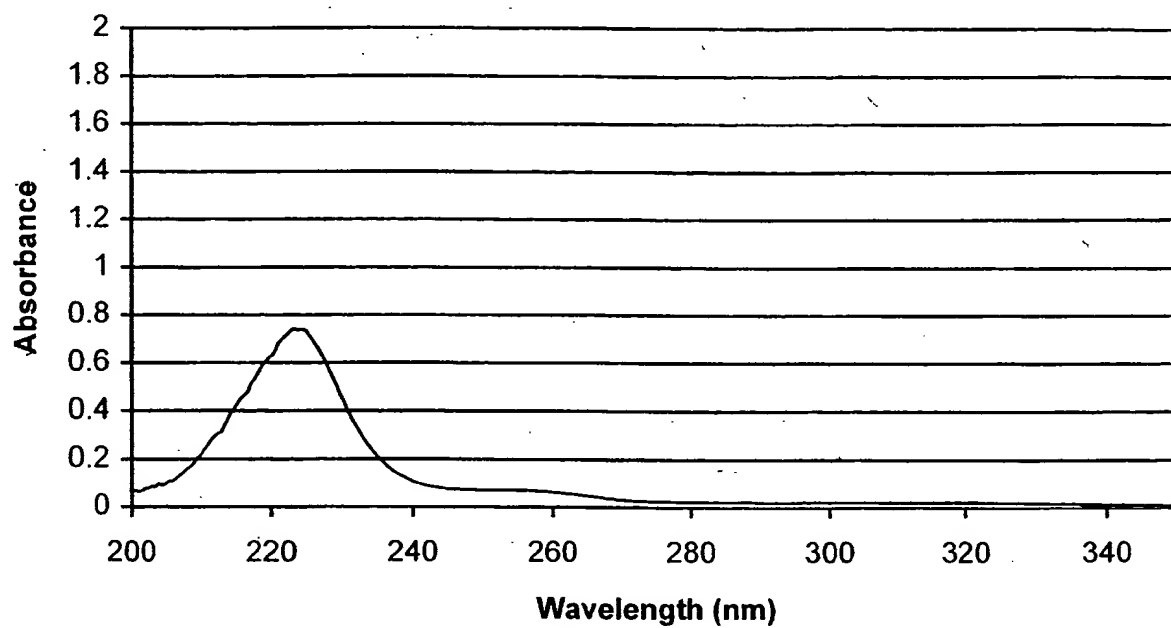
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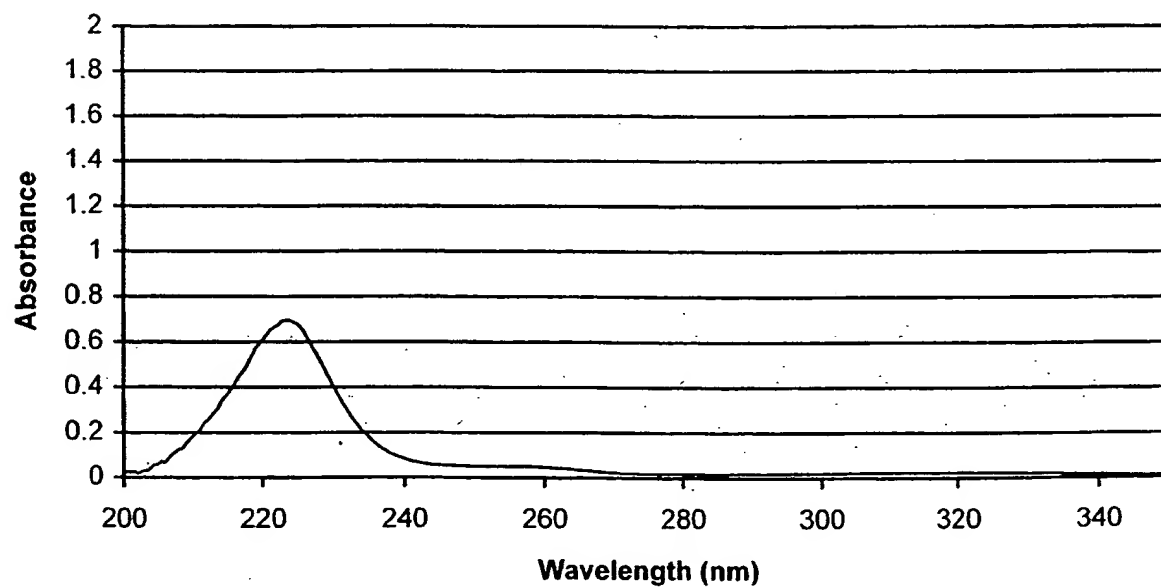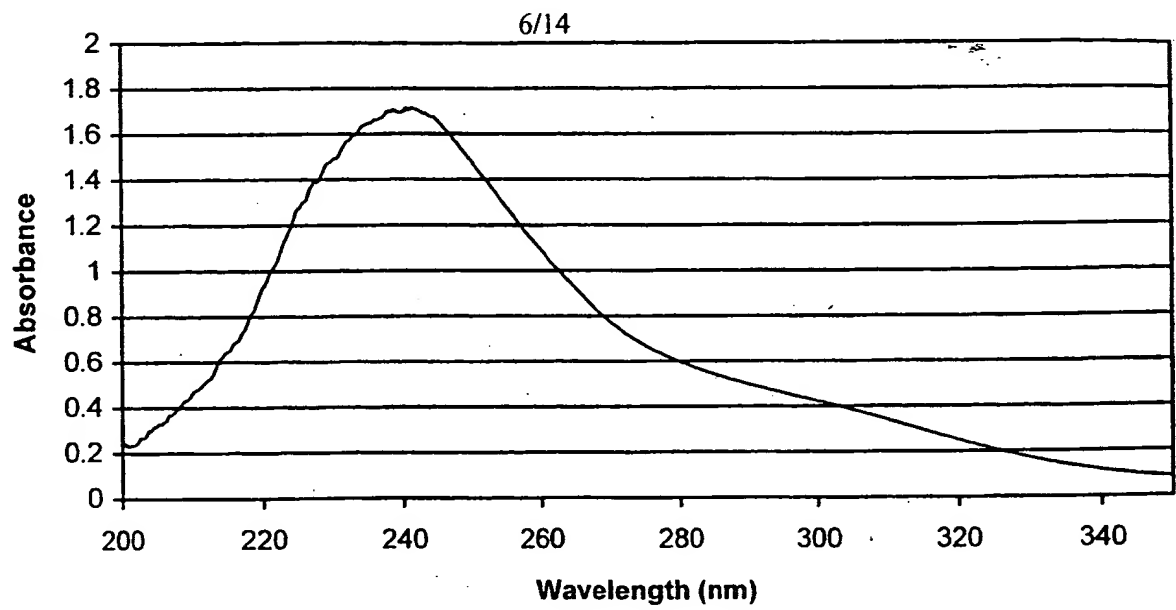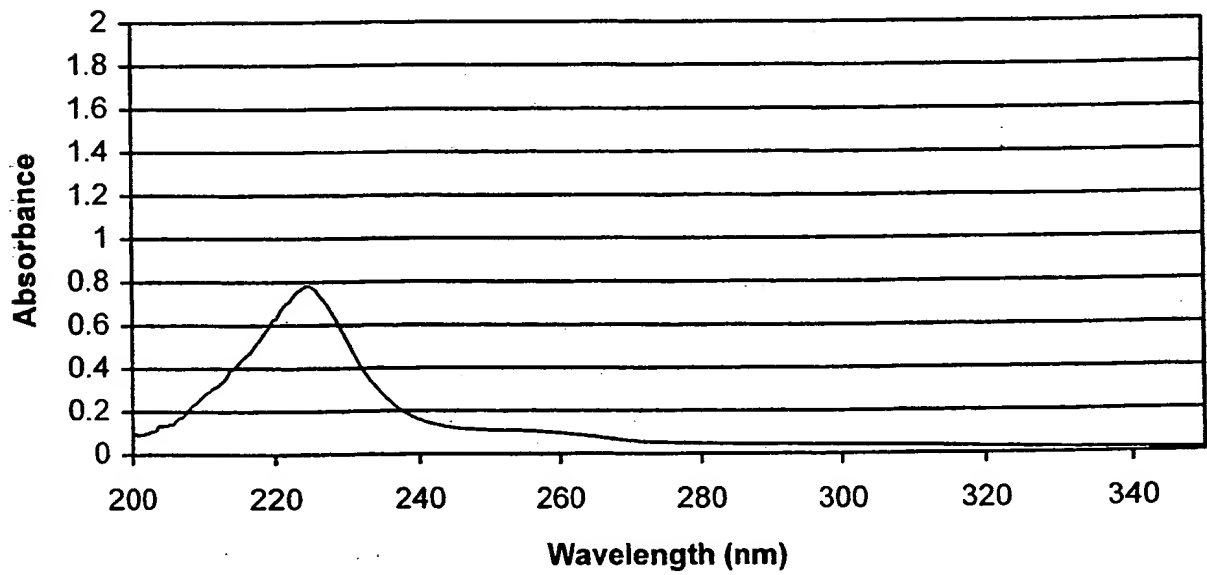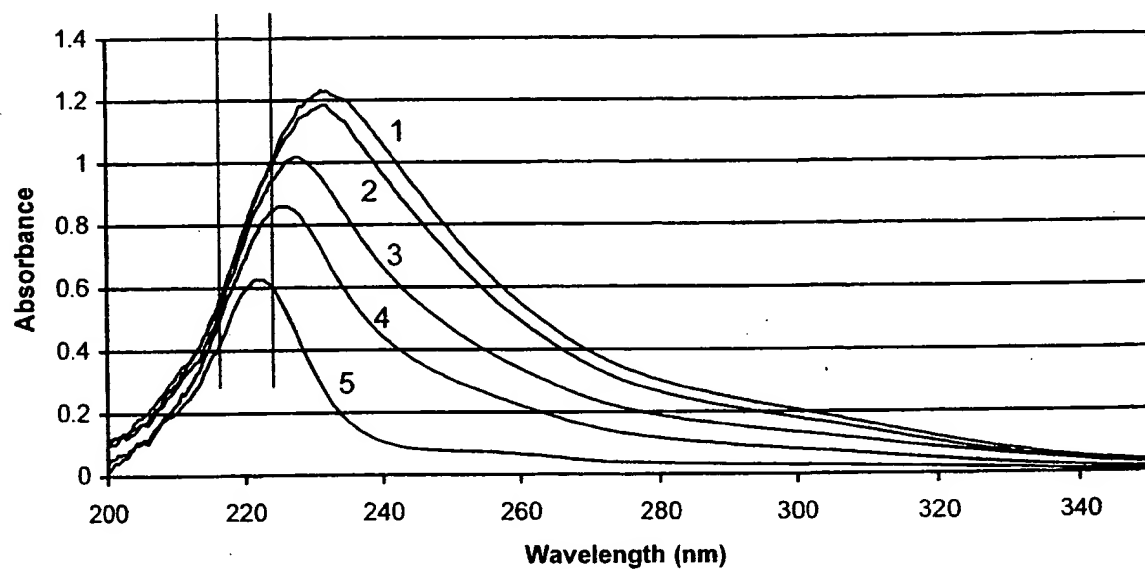

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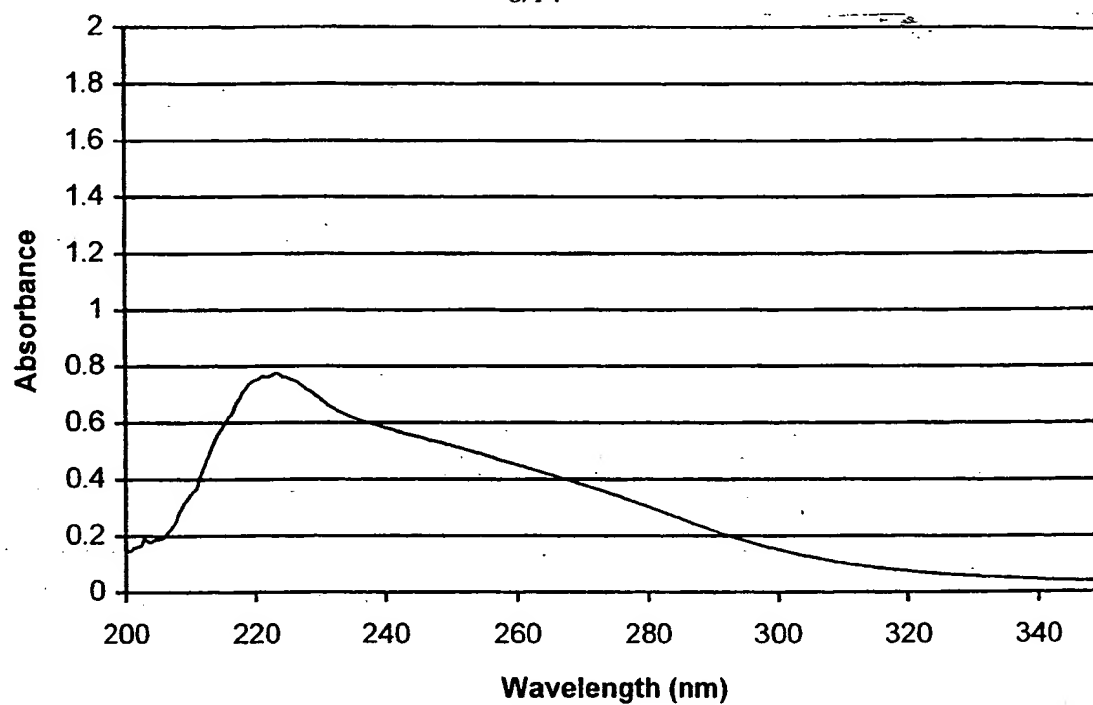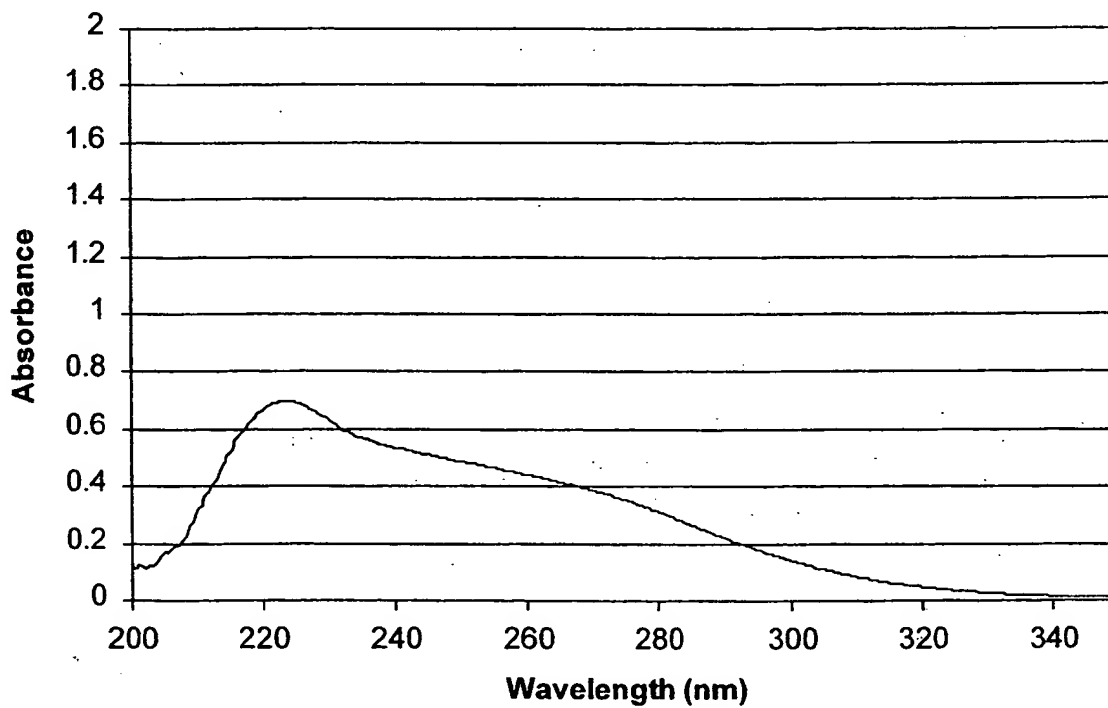
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Figure 6B

Figure 7

Figure 8A

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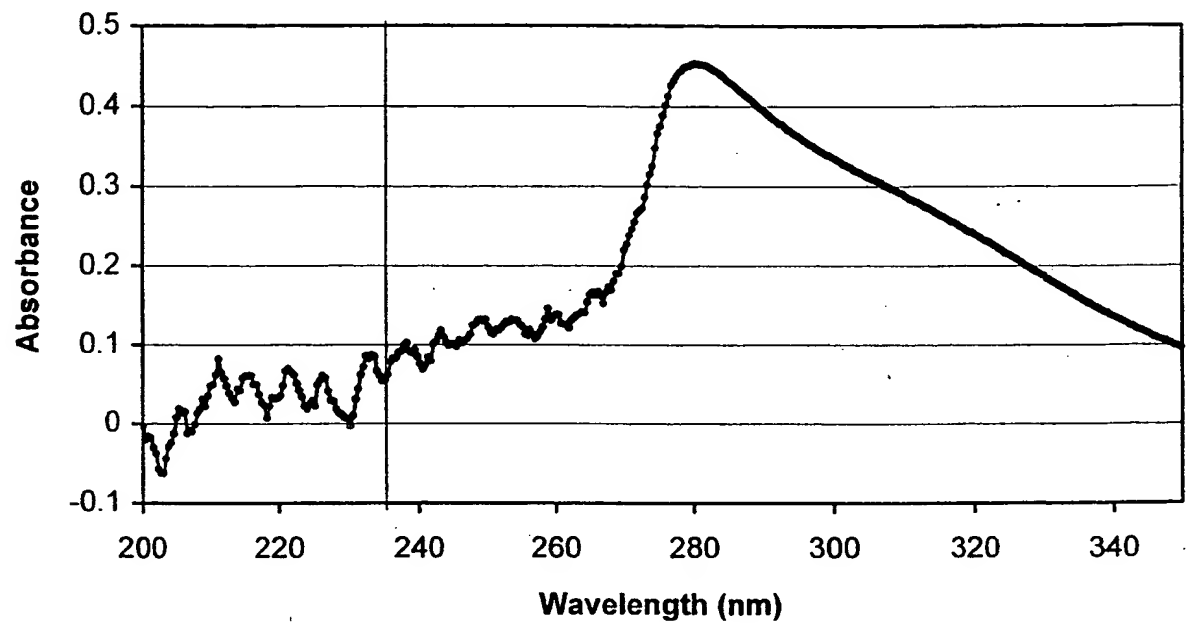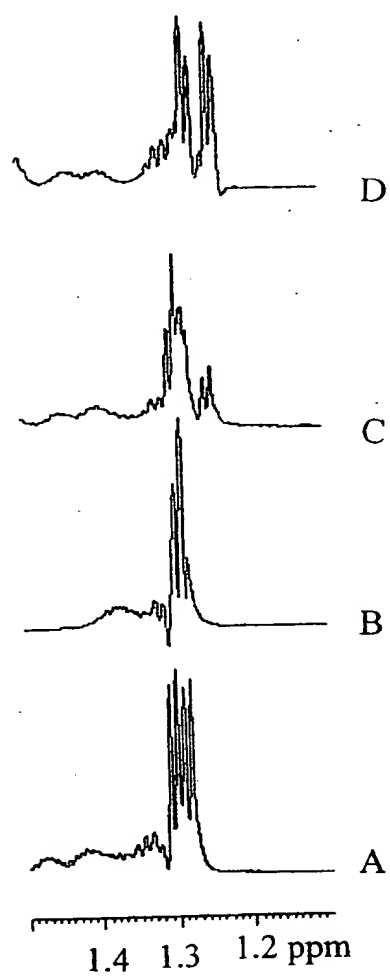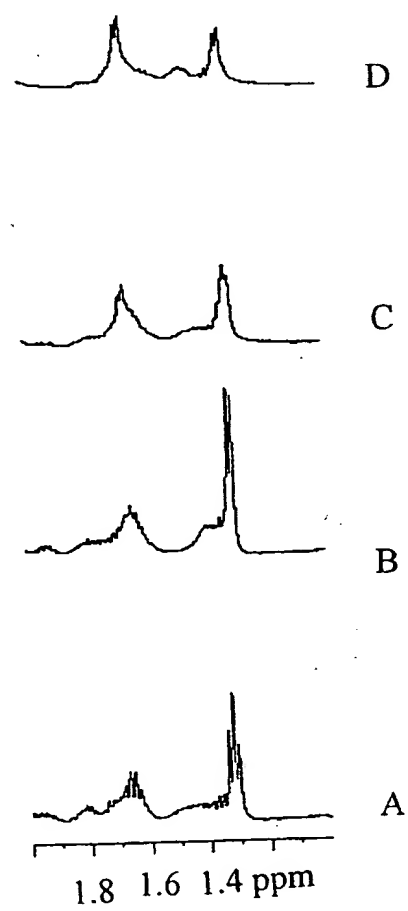
Figure 9

Figure 10

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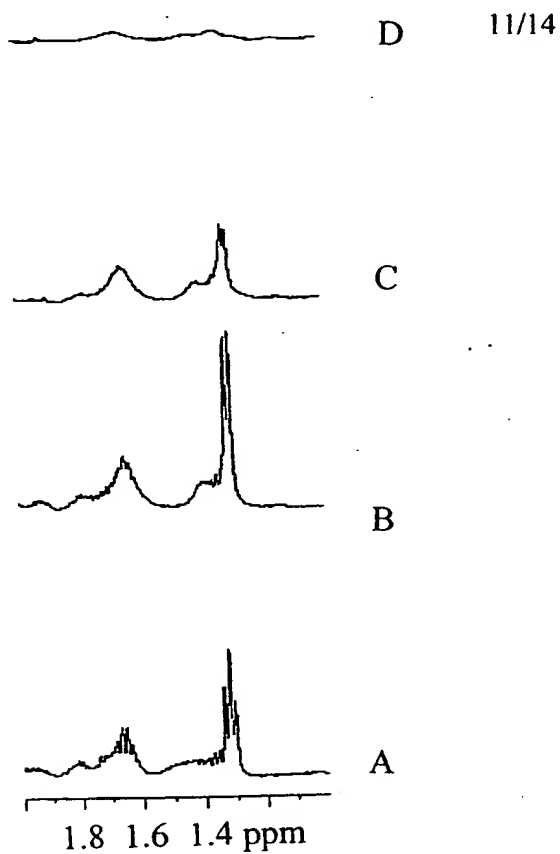
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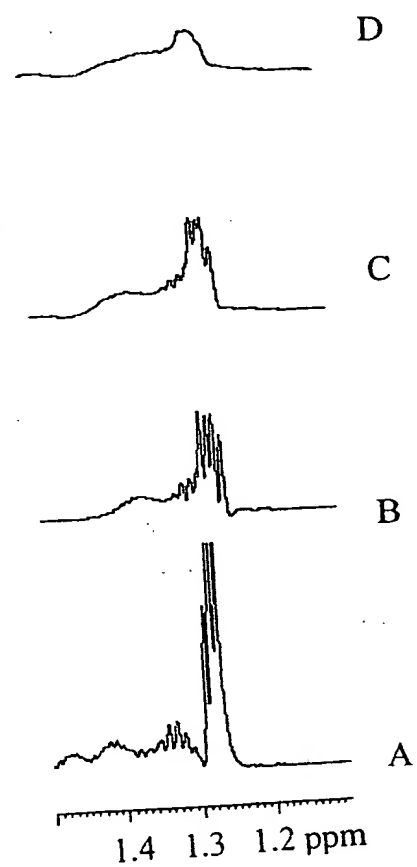
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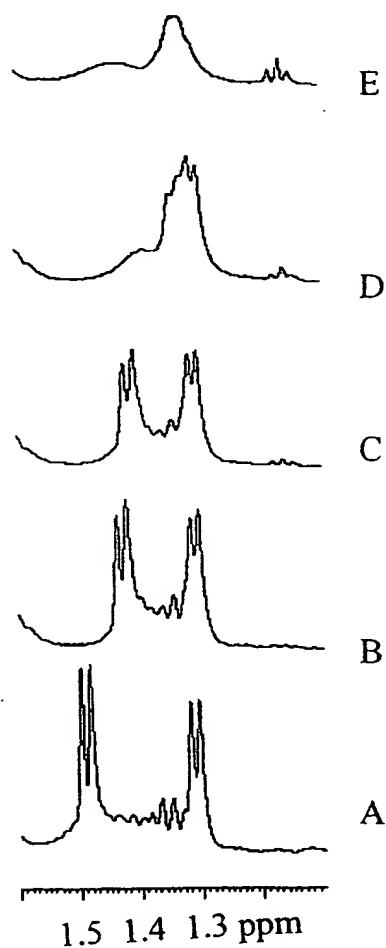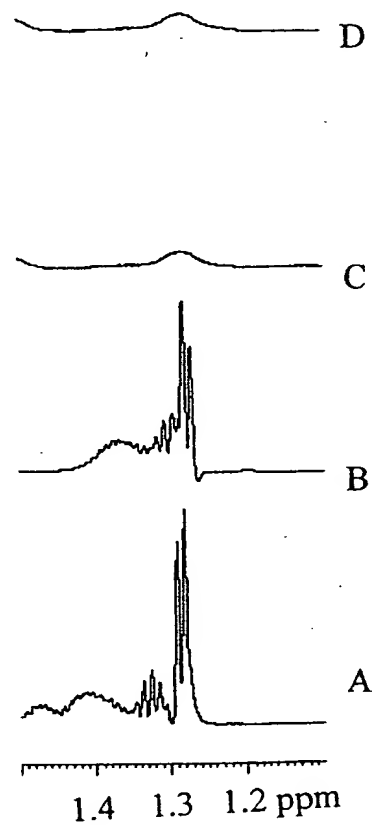
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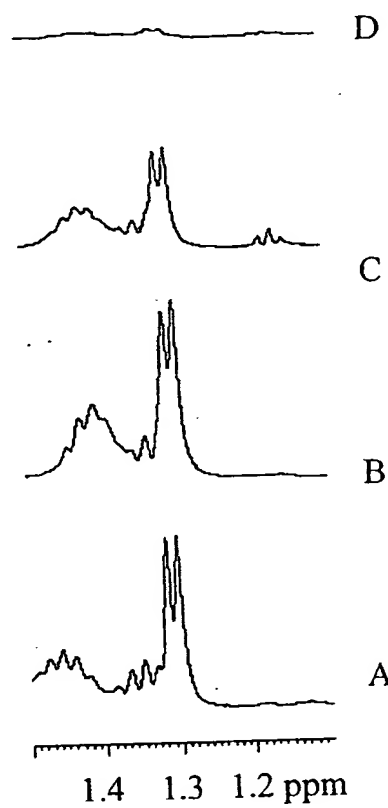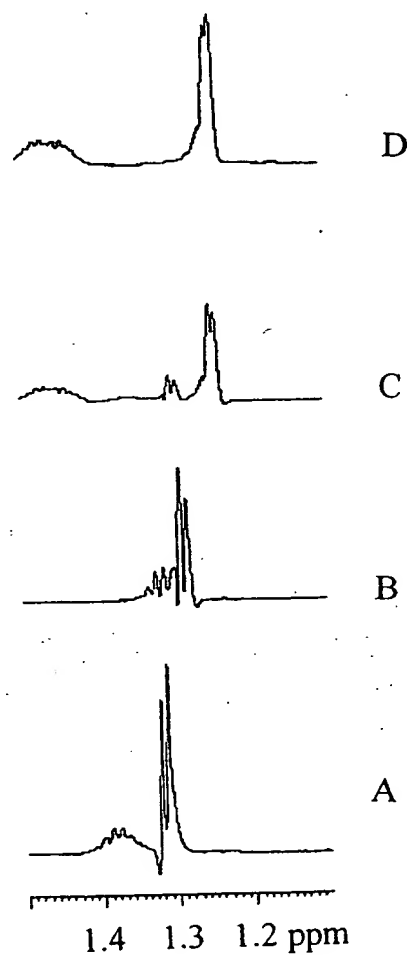
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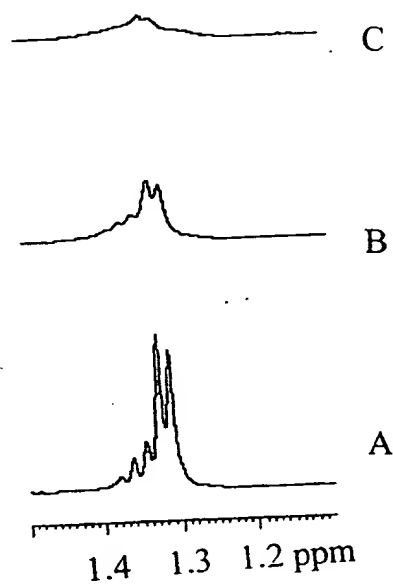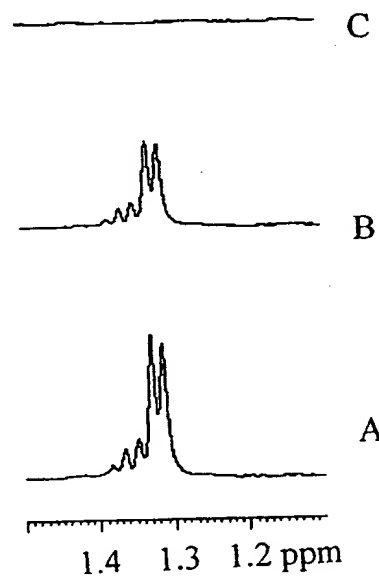
Figure 18

Figure 19

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SUBSTITUTE SHEET (RULE 26)

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<400> 2
Asp Ala His Lys Ser Glu Val Ala His Arg Phe Lys Asp Leu Gly Glu
  1           5                   10              .  15


Glu Asn Phe Lys Ala Leu Val Leu Ile Ala Phe Ala Gln Tyr Leu Gln
            20                  25                  30


Gln Cys Pro Phe Glu Asp His Val Lys Leu Val Asn Glu Val Thr Glu
            35                  40                  45


Phe Ala Lys Thr Cys Val Ala Asp Glu Ser Ala Glu Asn Cys Asp Lys
       50                  55                  60


Ser Leu His Thr Leu Phe Gly Asp Lys Leu Cys Thr Val Ala Thr Leu
 65                  70                  75                  80


Arg Glu Thr Tyr Gly Glu Met Ala Asp Cys Cys Ala Lys Gln Glu Pro
                85                  90                  95


Glu Arg Asn Glu Cys Phe Leu Gln His Lys Asp Asp Asn Pro Asn Leu
            100                 105                 110


Pro Arg Leu Val Arg Pro Glu Val Asp Val Met Cys Thr Ala Phe His
            115                 .120                125


Asp Asn Glu Glu Thr Phe Leu Lys Lys Tyr Leu Tyr Glu Ile Ala Arg
       130                 135                 140


Arg His Pro Tyr Phe Tyr Ala Pro Glu Leu Leu Phe Phe Ala Lys Arg
145                 150                 155                 160


Tyr Lys Ala Ala Phe Thr Glu Cys Cys Gln Ala Ala Asp Lys Ala Ala
                165                 170                 175
```

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SUBSTITUTE SHEET (RULE 26)

Cys Leu Leu Pro Lys Leu Asp Glu Leu Arg Asp Glu Gly Lys Ala Ser
         180   185   190

Ser Ala Lys Gln Arg Leu Lys Cys Ala Ser Leu Gln Lys Phe Gly Glu
         195   200   205

Arg Ala Phe Lys Ala Trp Ala Val Ala Arg Leu Ser Gln Arg Phe Pro
    210   215   220

Lys Ala Glu Phe Ala Glu Val Ser Lys Leu Val Thr Asp Leu Thr Lys
225   230   235   240

Val His Thr Glu Cys Cys His Gly Asp Leu Leu Glu Cys Ala Asp Asp
             245   250   255

Arg Ala Asp Leu Ala Lys Tyr Ile Cys Glu Asn Gln Asp Ser Ile Ser
         260   265   270

Ser Lys Leu Lys Glu Cys Cys Glu Lys Pro Leu Leu Glu Lys Ser His
         275   280   285

Cys Ile Ala Glu Val Glu Asn Asp Glu Met Pro Ala Asp Leu Pro Ser
    290   295   300

Leu Ala Ala Asp Phe Val Glu Ser Lys Asp Val Cys Lys Asn Tyr Ala
305   310   315   320

Glu Ala Lys Asp Val Phe Leu Gly Met Phe Leu Tyr Glu Tyr Ala Arg
             325   330   335

Arg His Pro Asp Tyr Ser Val Val Leu Leu Leu Arg Leu Ala Lys Thr
         340   345   350

Tyr Glu Thr Thr Leu Glu Lys Cys Cys Ala Ala Ala Asp Pro His Glu
    355   360   365

Cys Tyr Ala Lys Val Phe Asp Glu Phe Lys Pro Leu Val Glu Glu Pro
    370   375   380

Gln Asn Leu Ile Lys Gln Asn Cys Glu Leu Phe Glu Gln Leu Gly Glu
385   390   395   400

Tyr Lys Phe Gln Asn Ala Leu Leu Val Arg Tyr Thr Lys Lys Val Pro
         405   410   415

Gln Val Ser Thr Pro Thr Leu Val Glu Val Ser Arg Asn Leu Gly Lys
         420   425   430

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SUBSTITUTE SHEET (RULE 26)

```
Val Gly Ser Lys Cys Cys Lys His Pro Glu Ala Lys Arg Met Pro Cys
        435             440             445

Ala Glu Asp Tyr Leu Ser Val Val Leu Asn Gln Leu Cys Val Leu His
        450             455             460

Glu Lys Thr Pro Val Ser Asp Arg Val Thr Lys Cys Cys Thr Glu Ser
465             470             475             480

Leu Val Asn Arg Arg Pro Cys Phe Ser Ala Leu Glu Val Asp Glu Thr
            485             490             495

Tyr Val Pro Lys Glu Phe Asn Ala Glu Thr Phe Thr Phe His Ala Asp
            500             505             510

Ile Cys Thr Leu Ser Glu Lys Glu Arg Gln Ile Lys Lys Gln Thr Ala
        515             520             525

Leu Val Glu Leu Val Lys His Lys Pro Lys Ala Thr Lys Glu Gln Leu
        530             535             540

Lys Ala Val Met Asp Asp Phe Ala Ala Phe Val Glu Lys Cys Cys Lys
545             550             555             560

Ala Asp Asp Lys Glu Thr Cys Phe Ala Glu Glu Gly Lys Lys Leu Val
            565             570             575

Ala Ala Ser Gln Ala Ala Leu Gly Leu
            580             585
```

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INTERNATIONAL SEARCH REPORT

A.   CLASSIFICATION OF SUBJECT MATTER

IPC(7)   :G0IN 21/00, 21/29, 31/22, 33/543, 33/00, 33/53; C12Q 1/00

US CL   :Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

B.   FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. :   436/86, 518, 903, 904; 435/4, 7.9, 810; 422/55.61, 82.05, 82.09

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

STN, BIOSIS, MEDLINE, USAPATFUL

C.   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,227,307 A (BAR-OR et al) 13 July 1993, see entire document.	1-18 ---------- 19-35
Y	US 5,290,519 A (BAR-OR et al) 01 March 1994, see entire document.	36-42

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

	Special categories of cited documents:	"T"	later document published after the international filing d. e or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 DECEMBER 1999	07 FEB 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer PADMA BASKAR
Facsimile No. (703) 305-3230	Telephone No. (703) 308-0196

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/22905

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
   1-35 and 36-42

Remark on Protest   ☐ The additional search fees were accompanied by the applicant's protest.

   ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet(1))(July 1992)★

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

436/86, 518, 903, 904; 435/4, 7.9, 810; 422/55.61, 82.05, 82.09

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I, claims 1-35 and 36-42 drawn to a method for detecting the occurrence or non-occurrence of ischemic event and a kit which utilizes an immunoassay.

Group II, claims 43-46 and 47-51 drawn to another method for detecting the occurrence or non-occurrence of ischemic event and a kit which utilizes metal affinity diagnostic kit.

Group III, claims 52-55 drawn to monoclonal antibody directed to an epitope at the N-terminus of SEQ.ID NO.1.

Group IV, claims 56 drawn to monoclonal antibody directed to an epitope at the N-terminus of SEQ.ID NO.2.

Group V, claims 57-64 drawn to a calibrator composition and a method of calibrating an analyzer that detects or measures an ischemic event.

The inventions listed as Groups I to V do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: Group I drawn to a method for detecting the occurrence or non-occurrence of ischemic event and a kit which utilizes an immunoassay whereas Group II, drawn to another method for detecting the occurrence or non-occurrence of ischemic event and a kit which utilizes metal affinity diagnostic kit. These two methods are distinct and different in utilizing different steps, reagents and result in different outcome. Group III is a monoclonal antibody directed to an epitope at the N-terminus of the albumin which lacks the four, three, and two amino acid of SEQ. ID. NO. 1 where as Group IV, drawn to a structurally different monoclonal antibody directed to an epitope at the N-terminus of SEQ. ID. NO. 2. Group V to a calibrator composition and a method of calibrating an analyzer that detects or measures an ischemic event. This method is distinct and different from I and II in utilizing different steps, reagents and result in different outcome.